THE DEVELOPMENT OF A FRAMEWORK FOR ENHANCING IN-SERVICE LIFE SCIENCES TEACHERS' READINESS TO ADOPT FOURTH INDUSTRIAL REVOLUTION (4IR)-BASED INSTRUCTIONAL STRATEGIES

By

MARCELL MC KNIGHT

Submitted in the fulfilment of the requirements for the degree of

Doctor of Philosophy

In

CURRICULUM STUDIES

In the

COLLEGE OF EDUCATION

At the

UNIVERSITY OF SOUTH AFRICA

SUPERVISOR**: PROFESSOR L. MNGUNI**

2023

DECLARATION

I, Marcell Mc Knight declare that **THE DEVELOPMENT OF A FRAMEWORK FOR ENHANCING IN-SERVICE LIFE SCIENCES TEACHERS' READINESS TO ADOPT FOURTH INDUSTRIAL REVOLUTION (4IR)-BASED INSTRUCTIONAL STRATEGIES** is my work and that all the resources used or quoted have been acknowledged and referenced.

SIGNATURE: DATE: 12 February 2024

Student number: 10055959

DEDICATION

This thesis is dedicated to my son, Colby. May the submission of it serve as an inspiration for him to value education, pursue knowledge and believe in himself on his educational and life journey.

ACKNOWLEDGEMENTS

ABSTRACT

Past industrial revolutions have influenced education due to the changing needs of society during them. South Africa stands on the precipice of educational change, emanating from the influence of the Fourth Industrial Revolution (4IR) as it is still in the planning stage of policy and implementation related to the 4IR. This educational change will influence the instructional strategies adopted by teachers. This qualitative case study within the interpretive paradigm conducted in the province of KwaZulu-Natal aimed to develop a framework to enhance in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies as teachers shape change efforts. Ten in-service Life Sciences teachers, teaching Grades 10 to 12 within the Department of Basic Education (DBE), were purposively and conveniently sampled for the current research. Data was collected through open-ended questionnaires, semi-structured interviews, and document analysis. The current research was framed by a theoretical framework that combined theories relevant to the phenomenon which included the Revised Readiness for Change Model (RRCM), (Holt et al., 2007), the role of attitudes on the readiness for change (Kondakci et al., 2017), the influence of the 4IR understandings on the readiness for change and the Unified Theory of Acceptance and Use of Technology (UTAUT), (Venkatesh et al., 2003). Adopting guided analysis to analyse the data collected, it was found that the participants have varying degrees of readiness to adopt 4IR-based instructional strategies, exhibiting aspects that support and stifle the adoption of 4IR-based instructional strategies. This informed the development of a framework, a professional development initiative, to enhance in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies. The framework serves as a recommendation based on the findings. Other recommendations include that governmental educational authorities procure the required resources to ensure a standardised delivery of the curriculum and that Life Sciences teachers reflect on their current practice to assess if it is learner-centred or teacher-centred. Furthermore, it is recommended that similar research be conducted in the other phases, provinces and districts. This may unearth different findings due to the diverse contexts. These findings could aid in refining the framework.

Keywords: Educational change, Fourth Industrial Revolution, Framework, Instructional strategies, Life Sciences, Readiness

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LIST OF ACRONYMS

1IR	First Industrial Revolution
2IR	Second Industrial Revolution
3IR	Third Industrial Revolution
4IR	Fourth Industrial Revolution
AI	Artificial Intelligence
AIDS	Acquired Immunodeficiency Syndrome
CAPS	Curriculum and Assessment Policy
COVID–19	Coronavirus-19
DBE	Department of Basic Education
HIV	Human Immunodeficiency Virus
ICT	Information and Communication Technology
IKS	Indigenous Knowledge Systems
IoT	Internet of Things
MOOC	Massive Open Online Course
NCS	National Curriculum Statement
NOS	Nature of Science
OCL	Online Collaborative Learning
P21CL	Partnership for Twenty-First Century Learning
RRCM	Revised Readiness for Change Model
SDL	Self-Directed Learning
SMOE	Saskatchewan Ministry of Education
STEM	Science, Technology, Engineering and Mathematics
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UTAUT	Unified Theory of Acceptance and Use of Technology
WEF	World Economic Forum

CHAPTER 1: PRELUDE TO THE JOURNEY

"You cannot wait until a house burns down to buy fire insurance on it. We cannot wait until there are massive dislocations in our society to prepare for the Fourth Industrial Revolution."

Robert J. Shiller

1.1 INTRODUCTION AND BACKGROUND

The success of a society is dependent on the quality of education it implements. According to Fomunyam (2019), education is a critical mechanism that is used to shape a society, a region or a country, considering this era where there is massive advancement in technology, economics and industrial knowledge. Moloi and Mhlanga (2021) posit that education is vital for an economy to compete globally. According to Gwata (2019), education is one of many tools that assists in connecting individuals to the workplace and supports employment by serving as a building block. In terms of employment, which can be linked to an economy's ability to compete globally, according to Moloi and Marwala (2020), traditional employment pathways are diminishing due to the advancing technologies of the Fourth Industrial Revolution (4IR). Therefore, expertise and readiness in infusing 4IR technologies into teaching practices are important for teachers (Avelino & Ismail, 2022). According to Razak et al. (2018), teaching competencies need to meet the present global demands, where teachers ensure that their expertise, understanding and readiness are aligned with the current economic demands. Junid et al. (2019) add that the 4IR impacts several areas, including education, as it requires a new array of skills. This suggests that the perception of education needs to be revisited as each previous industrial revolution demanded an applicable approach to be implemented to achieve its goals. The 4IR is no different.

The topic of the 4IR has garnered much interest with several scholars contributing to the discourse concerned with it (Butler-Adam, 2018; Gray, 2016; Menon & Castrillon, 2019; Peters, 2017; Schwab, 2016; Webber-Youngman, 2017; World Economic Forum [WEF], 2020). These contributions have been largely focused on defining the 4IR, the catalytic role it plays in the employment needs of society, and, due to the changing societal employment needs, its influence on education to prepare learners to be best equipped for the needs of society. The discourse indicates that nations undergo varying degrees of educational transformation due to the influence of the Fourth Industrial Revolution (4IR) on their societies. The following sections expand on the aspects of the discourse relevant to the 4IR to contextualise the current

research. Also contributing to this contextualisation is the framing of 4IR-based instructional strategies and teacher readiness.

1.1.1 Defining the 4IR

In 2016, Klaus Schwab, the founder of the WEF, conceived the term the 4IR and stated that "the fourth industrial revolution creates a world in which virtual and physical systems of manufacturing cooperate with each other in a flexible way at the global level" (Schwab, 2016, p. 1). He asserts that the 4IR started at the turn of the twenty-first century and builds on the Third Industrial Revolution (3IR), also known as the computer or digital revolution. The computer or digital revolution was initiated by the invention of semiconductors, mainframe computing, personal computing and, in the 1990s, the Internet.

The concept of the 4IR is the focus of the current research and needs immediate addressing to dismiss any concerns related to its relevance in terms of its timing. It could be assumed, due to the time that has elapsed since the 4IR's inception, that teachers are surely well-versed in 4IR-based instructional strategies which the current research addresses in terms of providing a framework to enhance the readiness of teachers to adopt such strategies. In response to this claim, Moloi and Mhlanga (2021) write that the influences of the 4IR vary from country to country.

South Africa is still in the planning stage of policy and implementation which includes education related to the 4IR when compared to global northern countries like Germany and the United States of America (Speringer & Schnelzer, 2019). Both countries launched their policy in 2011 and are therefore at an advanced stage of policy implementation while South Africa is not.

Since South Africa has made limited progress in the implementation of educational policies relevant to the 4IR, only in the last few years have efforts been made to implement new subjects in the curriculum in response to these developments. Thus far, the Department of Basic Education (DBE) has piloted a draft Coding and Robotics Curriculum for Grades R-8. It is planned that full-scale implementation for these grades will take place in 2024. Piloting for Grade 9 was planned for 2023 with full-scale implementation in 2025. These measures speak to the addition of new subjects and not to 4IR-based instructional strategies with which the current research is concerned.

According to Gray (2016), the 4IR is a confluence of several advancements. These advancements include innovative robotics, independent transport, artificial intelligence (AI), machine learning and biotechnology. Schwab (2016) further states that:

> The fourth industrial revolution, however, is not only about smart and connected machines and systems. Its scope is much wider. Occurring simultaneously are waves of further breakthroughs in areas ranging from gene sequencing to nanotechnology, from renewables to quantum computing. It is the fusion of these technologies and their interaction across the physical, digital and biological domains that make the fourth industrial revolution fundamentally different from previous revolutions. (p. 12)

The 4IR is unique to the other industrial revolutions due to the pace, range and systemic influence on the economy and society that has never been experienced before. It is driven across the board by technology influencing how people engage with technology with a considerable transformation in how we live and work (Marwala, 2020; Moloi & Marwala, 2020; Schulze, 2019; Schwab, 2015; Singaram & Mayer, 2022). Butler-Adam (2018) argues that the 4IR is a move in the global economy toward technological solutions. This suggests that technology is an intrinsic aspect of the 4IR and that this technology requires a paradigm shift by individuals in the organisation of several aspects of their lives.

1.1.2 The Influence of 4IR on the Employment Needs of Society

Technology, driving the 4IR, causes employment needs to change constantly in society. Future employment will be distinctive from what currently exists. According to the WEF (2016), 65% of learners entering primary school will eventually occupy employment that does not currently exist especially in the Science, Technology, Engineering, and Mathematics (STEM) fields.

That 4IR influences the nature of employment due to technological advances is corroborated by a principal who stated that he is preparing children of today for jobs in the future that do not exist yet, where there is a need to start introducing children to the ideal information technology to prepare the technicians and scientists of the future (BusinessTech, 2022). The DBE added that individuals require digital skills for future careers which will allow them to operate successfully in a digital era (BusinessTech, 2022). Therefore, it is important to prepare learners for this changing world.

Adding to the transformation in employment driven by the 4IR, trends suggest that in the long term because of AI more than half of today's jobs will not exist within the next 35 years as a more automated environment prevails (Butler-Adam, 2018). Developing the applicable skills is vital for any individual wishing to remain relevant in an increasingly automated workplace. This suggests that an individual needs to acquire the relevant skills to be relevant in terms of securing employment. These skills can be developed through education that is appropriate for their acquisition.

1.1.3 The 4IR Employment Needs Influencing Education

Academic institutions need to think differently about their teaching and learning approaches when preparing learners for the needs of the 4IR (Webber-Youngman, 2017). According to Menon and Castrillon (2019), new curricula and teaching approaches are required for education to deliver on the needs of society in the 4IR which suggests that teachers need to think differently about the instructional strategies they adopt.

Instructional strategies also referred to as teaching strategies or methods are broadly defined as planned procedures and activities used in teaching (Akdeniz, 2016; Canady & Rettig, 1996). Adding to this broad definition is that instructional strategies are teachers' actions used in tandem with activities that provide a stimulating learning environment that facilitates learning (Moore, 2000).

Nababan et al. (2020) add that in line with the 4IR being driven by technology, education in the 4IR is characterised by using digital technology where learning can occur constantly without space and time limitations. Considering the dynamic nature of technology, teachers must continually learn to improve their competencies. According to Hussin (2018), teachers need to relearn skills in preparation for the 4IR to align with its demands. There is also a need for a correlation between learners and teachers. Learners in the 4IR should not be taught by teachers who adopt instructional strategies applicable to the previous industrial revolutions.

1.1.4 4IR-Based Instructional Strategies

To frame and contextualise instructional strategies and therefore identify what 4IR-based instructional strategies are, consideration is given to the definition supplied by Schwab (2016) in Section 1.1.1 that the 4IR is driven by technology. The integration of information and communication technology (ICT) facilitates the development of critical skills required by

individuals in the 4IR. However, to contextualise 4IR-based instructional strategies for the current research is the acknowledgement that such strategies encompass more than the mere integration of ICT adopted by teachers in the classroom. This acknowledgement is informed by the skills required by individuals to cope and thrive in the 4IR. These skills are used in determining what 4IR-based instructional strategies are.

Gray (2016) recognises ten skills needed by an individual in the 4IR. These skills include "complex problem-solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence, judgement and decision-making, service orientation, negotiating and cognitive flexibility" (p. 2). The Partnership for Twenty-First Century Learning (P21CL), (2019), in its twenty-first-century knowledge-skills rainbow, identifies three overarching or broad skills that are necessary for the twenty-first century. These overarching skills are life and career skills, learning and innovation skills and media information and innovation skills. Each of these overarching skills is comprised of more specific skills. For example, learning and innovation skills are comprised of creativity and innovation skills, critical thinking and problem-solving skills, communication skills and collaboration skills.

The WEF (2020) adds that quality education in the 4IR known as Education 4.0 includes eight critical characteristics that content learning must have. Characteristics are divided into skills and the type of learning required to develop these skills. For example, skills include "global citizenship, innovation and creativity, technology, and interpersonal skills" (WEF, 2020, p. 7). Learning needs to be personalised and self-paced, accessible and inclusive, problem-based and collaborative and should be student-driven. The skills required in the 4IR and the characteristics of learning experiences suggest that the instructional strategies teachers adopt in the 4IR must involve ICT due to the 4IR being driven by technology and activities that include the skills required in the 4IR to facilitate their development.

Butler-Adam (2018) responds to the recognition of the skills to be developed in the 4IR by posing a question concerned with how institutions can adapt their approaches to developing individuals. An awareness of this question suggests that institutions and teachers need to change, adjust or modify their instructional strategies if required to facilitate learners' acquisition of the skills to succeed in the 4IR.

Reflecting on the aspects of the discourse concerned with the 4IR, the current research proposes a framework to enhance in-service Life Sciences, a subject in Grades 10 to 12, teachers'

readiness to adopt 4IR-based instructional strategies considering the influence of the 4IR on education in terms of teaching and learning. The focus on teacher readiness is rooted in the view that education, in general, is experiencing many challenges which include but are not limited to the type of learner currently in the school system (Nababan et al., 2020). Learners tend not to want to work together as they are accustomed to playing games on devices by themselves and therefore lack the necessary skills to work together. Not having these skills to work together impacts the teaching and learning process. According to Nababan et al. (2020), such challenges place importance on a teacher's role in the 4IR in overcoming such challenges to secure the success of education. Challenges more specific to Life Sciences education and related to the current research include the insufficient time available to cover the content and that teachers do not know the suitable instructional strategy to adopt for teaching and learning to take place (Spooner, Flowers, Lambert & Algozzine, 2008). Teachers' lack of knowledge of suitable instructional strategies to adopt is applicable to the current Life Sciences curriculum, the Curriculum and Assessment Policy (CAPS) for Life Sciences, implemented in 2012 in South Africa as it does not explicitly state the instructional strategy to be adopted by the teachers.

CAPS as a curriculum is an amendment to the National Curriculum Statement (NCS), previously implemented in South Africa. This amendment responded to concerns regarding the NCS which included its implementation, teachers being overburdened with administration, the different interpretations of it and the underperformance of learners (Johnson, Dempster & Hugo, 2011). These concerns applied to all subjects taught in South Africa. The development of CAPS responded to worldwide changes and the demands of the twenty-first century where exposure to different levels of skills and knowledge is required by learners as South Africa had new ideals and principles that needed to be mirrored in the curriculum (DBE, 2011). A purpose of CAPS is to equip learners with the knowledge, skills and values that facilitate self-fulfilment and significant participation in society as citizens, irrespective of their socioeconomic status, race, gender, physical or intellectual ability.

Concerning the CAPS for Life Sciences, according to the DBE (2011), the purpose of studying Life Sciences, a subject in the Further Education and Training band (Grades 10-12), is to develop scientific knowledge and understanding, science process skills and understanding of science's roles in society. The content covered in Life Sciences is categorised into four knowledge strands namely, Life at the Molecular, Cellular and Tissue Level, Life Processes in

Plants and Animals, Environmental Studies and Diversity, Change and Continuity (DBE, 2011). It is envisaged that these knowledge strands will be progressively developed during Grades 10 to 12. Three specific aims in Life Sciences relate to the development of the purposes of studying Life Sciences. These are, Specific Aim 1 which relates to knowing the subject content; Specific Aim 2 which relates to doing science (practical work and investigations); and Specific Aim 3 which relates to understanding the applications of Life Sciences in everyday life, as well as understanding the history of scientific discoveries and the relationship between indigenous knowledge and science (DBE, 2011).

As indicated above, teachers lack of knowledge of a suitable instructional strategy to adopt in their classroom practice is a challenge facing Life Sciences education where its implementation was envisioned to respond to the different interpretations of the NCS respectively. Therefore, even though CAPS was implemented to address this concern of the NCS, it has not. A possible reason for teachers not knowing a suitable instructional strategy could be due to their interpretations of CAPS as was the case with the NCS as it does not state the instructional strategy to be adopted by teachers. This is relevant to the current research as teachers' varied interpretations of the curriculum may affect their selection of instructional strategies in the 4IR which may influence their readiness to adopt 4IR-based instructional strategies.

1.1.5 Outlining Teacher Readiness

Section 1.1.4 established that due to the influence of the 4IR teachers may be required to change, adjust or modify their instructional strategies. Therefore, teacher readiness to adopt 4IR-based instructional strategies needs to be framed. Teacher readiness is framed by the aspects of the theoretical framework of the current research. This framing includes firstly, that an individual's readiness to change consists of various dimensions depicted in the Revised Readiness for Change Model (RRCM) (Holt et al., 2007). These dimensions are appropriateness, management support, self-efficacy and personal valence. The influence of these dimensions on teacher readiness is discussed in Section 2.3.1.

Secondly, the role of attitudes in the readiness for change (Kondakci et al., 2017) is discussed in Section 2.3.2. Attitudes are shaped by an array of forces such as job outcome forces, trust in the principal and colleagues, and process factors that support or resist change. Thirdly, the influence of the 4IR understandings on the readiness for change is discussed in Section 2.3.3.

Finally, related to technology driving the 4IR, the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) is used to explore teachers' readiness to use technology. The factors of the UTAUT are performance expectancy, effort expectancy, social influence and facilitating conditions. The influence of these factors on the acceptance and use of technology concerning teacher readiness is discussed in Section 2.3.7.

This Section outlined how teacher readiness is framed. Section 1.2 leading from this framing identifies and explores the problem that the current research addresses.

1.2 PROBLEM STATEMENT

The discourse around the 4IR showed that it influences the instructional strategies teachers adopt in their teaching practice which may include a change, adjustment or modification. The current research proposes a framework to enhance in-service Life Sciences teachers' readiness to adopt instructional strategies required to respond to the 4IR.

The proposed framework responds to the problem which is prefaced by the role of education in society. The problem is informed by the factors that hinder the implementation of educational change. These factors apply to educational change in a broad sense and therefore to varying degrees relevant to countries across the globe. This Section contextualises the problem in terms of these factors in South Africa with the implementation of past curriculum changes. These curriculum changes culminated in the current curriculum, namely CAPS. The Section also assesses the recent changes to education initiated by the Coronavirus (COVID-19) pandemic to further highlight the factors that hindered the implementation of change during this period. Features relevant to the 4IR in South Africa's basic education system are presented to reinforce the identification of the problem.

1.2.1 Role of Education in Society

Education is an instrument to combat critical national challenges that are regarded as societal issues such as global economic competitiveness, unemployment and race relations (Atkin & Black, 2003). More specific to Life Sciences is that an explicit curriculum ideology for Life Sciences in South Africa can lead to transformed behaviour of learners to limit the spread of HIV and AIDS (Mnguni, 2012). This suggests education and the Life Sciences curriculum play a role in addressing and combatting societal issues that are a national challenge.

The role of education in addressing societal issues is linked with educational change. According to Kondakci et al. (2017), economic, political and technological developments in society catalyse marginal or considerable educational change that ultimately affects individual schools. This suggests that educational change responds to societal developments. Recognising that societal developments bring about educational change led to the identification of the current research's problem statement. The 4IR is regarded as a societal development bringing about educational change in terms of the instructional strategies implemented by teachers.

1.2.2 Factors Hindering Educational Change Globally

Educational change is a multifaceted and complicated process (Waugh & Punch, 1987). According to Okello and Kagoire (1996, p. 124) whose study was conducted in Uganda, "Curriculum implementation, which is relevant to educational change is a network of varying activities involved in translating curriculum designs into classroom activities and changing people's attitudes to accept and participate in these activities". Several factors hinder the implementation of a well-devised curriculum in educational change. In a Nigerian study, the chief factor was found to be the lack of understanding of the changes by both teachers at the school level and experts outside the school (Alade, 2011). This suggests that the successful implementation of educational change is dependent on the preparedness of teachers who are key components in the enactment of such change. The importance of teachers is underscored by the view that teachers influence learning (Ornstein & Hunkins, 2004). Bybee (1993) adds to the importance of the teacher in the implementation of a curriculum by viewing teachers as the change agents shaping the nature of classroom instruction and curriculum change efforts. The current research addresses this change by developing a framework to enhance the readiness of teachers to adopt 4IR-based instructional strategies.

Adding to the chief factor identified by Alade (2011) that contributes to the unsuccessful implementation of a curriculum are the factors recognised by Okello and Kagoire (1996). These factors are:

- The lack of teaching and learning resources
- Limited training on changes in the curriculum to teachers
- Limited management support
- The preparation of the managers to direct the transition of the changed curriculum
- The amount of work of teachers

- Time limitations and the curriculum content

- The standard and number of teachers

- The readiness of both teachers and learners to accept the teaching approaches of the new curriculum

- Overcrowded classrooms

In a study done in Australia, an example of the factors hindering the successful implementation of educational change is that teachers are loaded with non-teaching duties like attending meetings which stop them from concentrating on their teaching (Scott & Dixon, 2008). This is an indication of time being a factor in hindering the implementation of the curriculum. Furthermore, concerning time, the quality of the teachers' work declined as they did not have the time to produce work of high quality, improve their teaching and produce professional learning resources. In Ethiopia, Tadessa and Meaza (2007) found that inadequate supervision, time misalignment with the school calendar, lack of material financial support and negative attitudes of teachers presented challenges for curriculum implementation.

The factors that hinder curriculum implementation which include the readiness of teachers to accept the teaching approaches and the negative attitudes towards educational change (Okello & Kagoire, 1996; Tadessa & Meaza, 2007) respectively resonate with the current research. The development of a framework to enhance teachers' readiness to adopt 4IR-based instructional strategies needs to include their attitudes to this change.

1.2.3 Factors Hindering Educational Change in South Africa

South Africa has experienced factors that have hindered the implementation of previous educational changes. The political change in this country served as a social development and ushered in several educational changes to the curriculum used in schools. The changes garnered much criticism and highlighted the factors that negatively influenced the implementation of these educational changes. Recognising these factors positions one to address them through the development of a framework to enhance the adoption of 4IR-based instructional strategies.

The criticism included the use of highly complex language and the lack of teacher consultation and involvement in the development of curriculum policies (Jansen & Taylor, 2003; Smit, 2001). The lack of consultation and involvement did not expose the teachers to the educational change which influenced the readiness of teachers for the change. Research on educational

change advocates for teacher involvement and policy delivery strategies for education (Alsubaie, 2016; Wongwanich et al., 2015). This indicates that achieving the core curriculum goals relies on a teacher's preparedness to execute it, which is fostered through their active engagement. Teacher involvement in this process identifies and encourages their readiness for change; however, policymakers need to ensure they provide support for teachers by allocating resources, offering training programmes and establishing a conducive environment that fosters continuous professional development.

According to Maharajh et al. (2016), teachers lacked knowledge of the CAPS policy and they blamed limited training and lack of support from subject advisors. Inadequate and inexpert teacher training offered limited practical engagement in the classroom resulting in an unstable teaching and learning environment (Maddock & Maroun, 2018). Teachers also expressed that they were bombarded with time-consuming paperwork which took away teaching time and that the implementation was too sudden. According to Wongwanich et al. (2015), training empowers teachers in preparation for them to successfully navigate educational change which speaks to the readiness of teachers. This highlights the value of training in the implementation of a new curriculum.

Another factor that hindered the implementation of CAPS was the lack of resources such as laboratory equipment (Maharajh et al., 2016). The shortage of resources still prevails in many rural schools in this country. Du Plessis and Mestry (2019) emphasised the importance of resources in schools by commenting that rural schools still experience poor resources such as no water, sanitation or electricity that need to be addressed to eliminate unsafe, dysfunctional and ineffective schools.

The lack of resources is a challenge education faces in the 4IR which relates to the current research. According to Kayembe and Nel (2019), these challenges include insufficient funding, inadequate infrastructure and a lack of human, technical and financial capacity. According to Moloi and Mhlanga (2021), basic education in South Africa which involves the participants of the current research is not ready for the 4IR on two fronts, namely, technology and teacher competence. Although there are some pockets of readiness in urban schools in terms of technology and teacher competence, many schools, especially the rural schools, did not have the necessary technologies or teacher competence to facilitate learning in the 4IR. This contrasts with the South African Minister of Basic Education, Angie Motshekga's assertion that the country is ready to tackle the 4IR (Ndlendle, 2019). Teachers in rural schools are still

dependent on traditional teaching methods such as using the chalkboard in their teaching practice. The assertion that there is a lack of the appropriate resources and teacher competence does indeed imply it will be difficult for teachers to implement changes in instructional strategies. The lack of resources is thus a major challenge in the 4IR. A logical inference can be that this will impact the implementation of educational programmes in the 4IR.

On the topic of the use of technology in the classroom, according to Khalo (2020), teachers to varying levels are integrating technology into their teaching practice. Their preferred tools include laptops and data projectors. This integration of technology at varying levels can be attributed to the availability of infrastructure for teachers. Infrastructural aspects such as the lack of internet access, the insufficient number of computers, and outdated software packages have hindered ICT implementation in African schools (Ghavifekr & Rosdy, 2015; Mostafa et al., 2017; Ojo & Adu, 2018; Van Rooy, 2012). This further suggests that teachers face challenges in integrating technology due to a lack of resources in the classroom influencing their readiness to adopt 4IR-based instructional strategies.

1.2.4 Factors Hindering Educational Change in the COVID-19 Pandemic

Section 1.2.1 highlighted societal developments influencing education. The unexpected contemporary phenomenon of the global COVID-19 pandemic was a human, economic and social crisis negatively affecting vulnerable social groups including the youth who require education (United Nations [UN], 2020). An evaluation of how education was managed during COVID-19 is relevant to the current research. According to the WEF (2020), changes to teaching and learning during this period allow for a glimpse at how education could change in the long term. Reflecting on this period is invaluable in adapting to the degree of educational change emanating from the influence of the 4IR on education.

According to the UN (2020), the closure of schools affected over one billion youth as they were not physically in school due to the measures adopted to limit social interaction between individuals and the spread of COVID-19. The closure and reopening of schools at various stages of the pandemic is evidence of educational change. It required educational managers, teachers and learners to rethink traditional schooling. In a short period, teachers were compelled to adapt to a changing teaching environment due to limited social interactions during the COVID-19 epoch. COVID-19 forced an adjustment in the way that teachers and learners experience teaching and learning.

The influence of the COVID-19 pandemic on teaching and learning was a change from traditional teaching and learning methods to technological ones which are viewed as non-traditional (Murgatrotd, 2020; Subedi et al., 2020). Traditional schooling is face-to-face contact between teachers and learners. The non-face-to-face contact brought about an adjustment or modification to teaching and learning practices where teachers had to adapt regardless of the context (United Nations Educational, Scientific and Cultural Organisation [UNESCO], United Nations International Children's Emergency Fund & World Bank, 2020). At the start of COVID-19, there was a need for the use of creative teaching methods to assist students at home via interactive applications which facilitated online teaching. Technology-based interventions were adopted to facilitate teaching and learning which included the use of radio, television and online teaching applications such as Microsoft Teams, Zoom and Google Classroom which required internet connectivity to support learners (Noor et al., 2020). The reopening of schools at various stages during COVID-19 saw the implementation of blended learning. According to Graham (2004), blended learning refers to the integration of traditional educational methods with electronic instruction, effectively combining education with technology.

According to the WEF (2020), COVID-19 reshaped education through the forging of partnerships between diverse stakeholders such as governments, publishers, education professionals, technology providers and telecom network operators to find innovative teaching solutions during the pandemic. This suggests that there was communication and consultation between the government and teachers (education professionals). However, this was not the case in South Africa as there was no meaningful engagement between the government and teachers in policy development during the pandemic (Sayed et al., 2021). Teachers were not consulted on aspects related to teaching and learning which included alternatives to the traditional practices used to deliver the curriculum. Viennet and Pont (2017) state that the successful implementation of policy is dependent on healthy consultation with teachers. Carvalho et al. (2020) and Sherif et al. (2020) add that consulting teachers in policy development and its implementation is essential as they have a deep understanding of their learners and the community. This non-consultation of teachers as a hindering factor was repeated as was the case with the implementation of CAPS.

The lack of adequate and expert training hindering the implementation of CAPS highlighted in Section 1.2.3 is relevant to the adoption of technological-based measures during COVID-19. According to UNESCO (2020), six out of 10 teachers globally expressed an under-

preparedness for online teaching as they felt their training and support were deficient. The deficiency in their training served to further highlight teachers' ICT limitations in the West and in Sub-Saharan Africa. Many teachers in the West lacked basic ICT skills even though a suitable infrastructure prevailed, while in Sub-Saharan Africa 50% of secondary teachers received minimal professional development where ICT skills were not included (UNESCO, 2020). According to Sayed et al. (2021), teachers in South Africa received limited training related to CAPS during COVID-19. The under-preparedness of teachers for COVID-19 to enact change highlights the challenges faced in implementing educational change.

The factors that hindered the implementation of CAPS and educational change during COVID-19 are consistent with the factors identified by Alade (2011) and Okello and Kagoire (1996). These hindering factors with the implementation of CAPS which still prevail support the claim that teachers are under-prepared to absorb the intricacies of the curriculum which speaks to teacher readiness. This suggests that South Africa has not taken to heart the lessons learned from previous educational changes in terms of the factors that hinder their implementation. Furthermore, the prevailing factors contribute to teacher readiness to implement change in the 4IR. The current research focuses on teacher readiness for change through the development of a framework to enhance the adoption of 4IR-based instructional strategies. A framework that considers and attempts to mitigate the impact of the factors that influence educational change concerning the 4IR will, in part, allow teachers to navigate the educational change.

1.3 RESEARCH QUESTIONS

The problem statement of the current research is concerned with the factors that hinder the implementation of educational change. In responding to the problem, the following research questions were addressed:

Main research question:

What framework can be developed for enhancing in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies?

In addressing the main research question the following sub-research questions were explored:

1. What is in-service Life Sciences teachers' understanding of 4IR-based instructional strategies?

2. What instructional strategies do in-service Life Sciences teachers intend to adopt in the 4IR?

3. To what extent are in-service Life Sciences teachers' understandings of 4IR-based instructional strategies and their intended instructional strategies in line with 4IR-based instructional strategies?

4. What is the readiness of in-service Life Sciences teachers to adopt 4IR-based instructional strategies?

The answers to these questions were synthesised to create the intended framework.

1.4 RATIONALE

The rationale for the current research is based on a comprehensive review of literature relevant to the phenomenon. There is firstly, an acknowledgement of relevant existing research which provides credibility and contributes to the rationale. It demonstrates that in establishing the rationale, the literature was reviewed in an impartial or unbiased manner and not in a manner that is open to question. Secondly, a gap in the existing research relevant to the phenomenon is done on two fronts. These fronts are the broad nature of research concerned with the readiness of teachers for the impact of the 4IR on education (Junid et al., 2019; Oke & Fernandes, 2020) and research has focused on the effectiveness of certain instructional strategies on learner performance (Badmus et al., 2019). There has been limited focus on teacher understanding of 4IR-based instructional strategies. Thirdly, the problem that the current research addresses is rooted in the prevailing factors that hinder the implementation of educational change (Section 1.2).

1.4.1 Existing Research

According to Oke and Fernandes (2020), there is limited literature on the 4IR in the education sector. This claim is contested because several studies have identified instructional strategies aligned with the idea that technology propels the 4IR, emphasising the prominence of technological solutions in the global economy (Schwab, 2016; Butler-Adam, 2018). Considering the role of technology in 4IR, research may not include the term 4IR in its title; however, research does exist on the use of technology in teachers' teaching practices.

For example, studies revealed several difficulties experienced by teachers with the use of ICT. These difficulties include the unavailability and limited access to resources that inhibit teachers

from employing new technologies in their teaching practice. According to Van Rooy (2012) stemming from the limited availability of computers, mobile devices and access to the internet, teachers are often unable to incorporate ICT in their teaching practice. Ojo and Adu (2018), in exploring the effectiveness of ICT in teaching and learning, commented that teachers can attempt to modify and maximise the limited resources available to enhance their teaching; however, this comes with a financial cost to teachers. Other factors which hinder the use of ICT in the classroom include inadequate resource organisation, inappropriate software and limited individual access of teachers to computers (Ghavifekr & Rosdy, 2015).

Section 1.2.4 explored the problem statement of the current research in terms of the influence of COVID-19 on education to categorise how education could be in the long term. A plethora of recent studies have investigated instructional strategies adopted by teachers during the pandemic. Intrinsic to these studies is the exploration of the use of ICT interventions. For example, Singh-Pillay and Naidoo (2020) explored STEM lecturers' reflections on the use of online technologies during the pandemic. It was found that lecturers use everyday communication applications to supplement more formal educational applications and that the accessibility of data enables online teaching. It was also found that technical training received for online teaching and misalignment of teaching pedagogy to the learning styles of students hindered online teaching.

Noor et al. (2020) investigated Pakistani teachers' perceptions of online teaching methods during the pandemic and found that teachers confronted challenges that were much like those highlighted by studies conducted before the pandemic (Ghavifekr & Rosdy, 2015; Ojo & Adu, 2018; Van Rooy, 2012). Additions to these challenges included uncooperative learners, low attendance of learners, teachers' technology confidence and limited ICT knowledge.

The discussion introducing the gaps in the research recognised that literature indirectly exists on the 4IR as there is considerable research concerned with the integration of technology. Technology is intrinsically linked to the 4IR. The discussion emphasised that this notion conflicts with Oke and Fernandes's (2020) view that there is limited research on 4IR in the education sector. Based on this, the rationale for the current research is that 4IR-based instructional strategies encompass more than technology (Section 1.1.4) owing to the acquisition of a wide range of skills. Therefore, it will establish or contribute knowledge that is holistic in its view of 4IR-based instructional strategies and teacher readiness to adopt them.

The challenges that teachers faced during COVID-19 (Section 1.2.4) when using technology in their teaching practice also added to the rationale of the current research. Proposing a framework to enhance teachers' readiness to adopt 4IR-based instructional strategies requires an understanding of these challenges. This understanding will contribute to the body of knowledge regarding these challenges.

1.4.2 Broad Nature of Research

There has been an attempt to explore the readiness of teachers for educational change and the influence of the 4IR; however, such explorations have been broad in terms of their focus while this research has a narrower focus. First, a study conducted in Australia explored the implementation of general educational change in terms of the correlation between teacher readiness and learner achievement (Lynch et al., 2017). Second, Life Sciences teachers have not been the sole participants. Science teachers in general were participants including Physical Science and Chemistry teachers (Junid et al., 2019). Third, the evaluation of the education sector was done by exploring the perceptions of stakeholders in the higher education sector in Africa (Oke & Fernandes, 2020). The current research contrasts with previous research as it engages with the South African Life Sciences teachers, who operate in the basic education context, and their readiness to adopt 4IR-based instructional strategies and not educational change in general. These aspects of the current research provide focus. In addition, it proposes a framework to enhance teacher readiness to adopt 4IR-based instructional strategies which previous research does not.

1.4.3 Effectiveness of Instructional Strategies on Learner Performance

Research on instructional strategies has predominantly been focused on the effectiveness of certain instructional strategies on learner performance and achievement (AgwuUdu, 2017; Audu, 2018; Bamidele & Yoade, 2017; Chukwu & Arokoyu, 2019; Gambari & Yusuf, 2017; Molla & Muche, 2018; Oluwatoyin & Gabriel, 2018; Sam et al., 2018; Wesonga & Aurah, 2019). Such research exhibited common features in terms of its aims, the participants (learners) and the subject area (STEM). The research explores the effectiveness of certain instructional strategies in African countries, for example, Nigeria and Ghana. However, limited research has been conducted in South Africa, making the current research different.

The commonalities in the studies on instructional strategies aid in identifying the problem that the current research sought to explore and understand will allow for discourse on how to

address it. The current research is concerned with the readiness of teachers and not the effectiveness of certain instructional strategies. Therefore, it attempts to fill a gap in the existing research.

1.4.4 Responding to the Research Problem

The research problem (Section 1.2) is rooted in the factors that hinder the implementation of educational change. Aspects which influenced the implementation included the lack of teacher consultation and involvement in policy development, the lack of resources and the lack of teacher professional development resulting in teachers feeling underprepared to enact the change (Sayed et al., 2021; Smit, 2001; UNESCO, 2020). Considering the factors which hinder the implementation of educational change, the current research aims to improve the implementation of educational change with the development of a framework which could be implemented to enhance in-service Life Sciences teachers' readiness or ability to adopt 4IR-based instructional strategies in the future.

An understanding of in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies may be used to inform decisions made by policymakers within the DBE. These decisions have an impact on the instructional strategies in-service Life Sciences teachers adopt in the 4IR. The decision-making has relevance as, according to Speringer and Schnelzer (2019), this country is still in the planning stage of policy and implementation related to the 4IR compared to countries in the Global North. These decisions are important as teachers will be practising in a changing environment that by its very nature demands that they face the challenges inherent in a space of uncertainty which compels them to make changes to their current teaching practices to successfully attain the vision of the new intended curriculum.

The understanding could also assist teacher training institutions in developing their curricula to prepare pre-service teachers and in-service teachers for teaching and learning that is dissimilar from their experiences as learners. Moloi and Mhlanga (2021) recommended the need for tertiary institutions to design learning programmes to introduce teachers to the 4IR.

The current research may generate solutions to address the country's weak position in global Science standards and learner performance in the National Senior Certificate Examination. According to Reddy et al. (2016), South Africa is ranked last out of 39 countries in Science at the Grade 9 level in the Trends in International Mathematics and Science Study. Solutions may lie in focusing on teachers' instructional strategies as many teachers who teach Life Sciences

also teach Natural Sciences. Secondly, learners do Natural Sciences before choosing Life Sciences for Grade 10. Collaborative teaching amongst colleagues in the different phases of basic education where there is a sharing of knowledge and skills may enable the learners to be better positioned to assimilate the instructional strategies implemented in Grades 10 to 12 as they would have already been introduced to them in a lower grade.

In terms of the current research possibly contributing to the improvement in learner performance in the National Senior Certificate Examination is that nationally, in 2022, Life Sciences was the second-highest non-language subject that candidates wrote. Mathematical Literacy was the highest. This suggests that a large number of learners are exposed to Life Sciences. In KwaZulu-Natal, 88 768 candidates wrote Life Sciences in the province, the highest in the country but 48.5 per cent of them did not achieve 40 per cent. This statistic of learner performance in the province could be contributing to learners not achieving a bachelor's pass, which is a requirement for university entrance. Considering the number of learners exposed to Life Sciences nationally and their performance in KwaZulu-Natal suggests that Life Sciences has a role to play in improving the National Senior Certificate achievement levels. A greater understanding of effective instructional strategies may aid decisions concerned with ensuring an improvement in learner performance.

1.5 RESEARCH AIMS

Closely aligned with the research questions (Section 1.3) are the research aims of the current research stated below. Firstly, the primary research aim is:

To develop a framework for enhancing in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies.

Secondly, to achieve this primary aim the following secondary aims, which are aligned with the research sub-questions, were pursued:

1. To determine in-service Life Sciences teachers' understanding of 4IR-based instructional strategies.
2. To determine what instructional strategies in-service Life Sciences teachers intend to adopt in the 4IR.
3. To assess to what extent in-service Life Sciences teachers' understandings and intended practice of instructional strategies are in line with 4IR-based instructional strategies.

4. To determine and explore the readiness of in-service Life Sciences teachers to adopt 4IR-based instructional strategies.

1.6 THESIS OUTLINE

Chapter 1: This chapter introduces and provides the contextual background of the current research. It orientates the reader to the phenomenon, problem, research questions, rationale and aims.

Chapter 2: This chapter provides a synopsis of the theory that underpins the current research and is informed by relevant concepts. These include educational change, other industrial revolutions and their impact on education, instructional strategies and curriculum. It also explores the theoretical framework of the current research. According to Wells (2007), theories reveal how information is received, processed and retained during research. The chapter provides a basis for the current research.

Chapter 3: This chapter engages with the elements of the research strategy of the current research which includes the research paradigm (interpretive), the research approach (qualitative), the research design (case study), sampling (purposive, convenience and snowball), the data collection instruments (open-ended questionnaires, semi-structured interviews and document analysis), data analysis (guided analysis), trustworthiness (credibility, dependability, transferability, conformability), and ethical considerations.

Chapter 4: Results are presented and substantiated by evidence in this chapter which are informed by the analysis of data produced by participants (in-service Life Sciences teachers). The evidence of the results is presented in tables with the use of verbatim quotations.

Chapter 5: This chapter discusses the results presented in Chapter 4 which involves applying the theories explored in Chapter 2 to validate or invalidate them. This chapter considers the findings in developing a framework to enhance in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies.

Chapter 6: This chapter concludes the current research by summarising each chapter, and findings related to the research questions. It responds to and presents recommendations informed by these findings.

1.7 CHAPTER SUMMARY

Due to the influence of the 4IR, a level of educational change is experienced with the instructional strategies teachers incorporate in their teaching practices. The current research aims to develop a framework to enhance in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies to assist in the effective implementation of educational change. To develop this framework, there is a need to determine the teachers' readiness to adopt 4IR-based instructional strategies. Establishing teachers' readiness is to answer and understand the teachers' responses related to the sub-questions of the current research. In doing so the aims of the study will be achieved. It is envisaged that the current research will contribute to the existing knowledge concerned with this topic. Further, it may initiate a discourse that interrogates its findings which could inform decisions made by the governmental educational authorities that have an impact on the instructional strategies in-service Life Sciences teachers adopt in the 4IR. An understanding of 4IR-based instructional strategies could also assist teacher training institutions in the planning of their programmes.

The next chapter presents the theoretical underpinnings of the current research through the appraisal of literature relevant to it. The presentation of the theory also involves an explanation of the theoretical framework employed to determine in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies.

CHAPTER 2: EXPLORING THE JOURNEY'S TERRAIN

"The illiterate of the twenty-first century will not be those who cannot read and write, but those who cannot learn, unlearn and relearn."

Alvin Toffler

2.1 INTRODUCTION

The previous chapter provided the contextual background of the current research and orientated the reader with its various aspects. This chapter provides the theoretical underpinning of the current research, which became apparent after an extensive review of the relevant literature. Reviewing literature supplies the broad themes of research as it demonstrates the possible contribution the research could make to the existing body of knowledge about the topic.

The chapter commences with a description of the key aspects found in the title of the current research. These include the 4IR, education and instructional strategies and the justification of the theoretical framework which frames the readiness for change. It then discusses other relevant themes which are centred around theories relevant to and within the curriculum, including teaching and learning and instructional design. In discussing these themes, the researcher made an effort to relate them to the aspects of the current research. The literature reviewed in this chapter is guided by addressing the main research question which is concerned with the development of a framework that will enhance in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies.

2.2 THE FOURTH INDUSTRIAL REVOLUTION

The review of the discourse around the 4IR (Section 1.1.1) highlighted that it is quite different from other industrial revolutions due to the pace, range and system influence on the economy and society. A manifestation of this uniqueness is that it influences all aspects of our daily lives.

According to Marwala (2020), to secure an understanding of the 4IR, the first three industrial revolutions need to be reviewed. Peters (2017) states that "society has been confronted with four industrial revolutions, namely the machine age, the age of electricity, the age of electronics, and the age of the internet as a platform" (p. 1). Common to the industrial revolutions is the fundamental transformation of society due to the innovation of specific technologies (Marwala, 2020; Moloi & Marwala, 2020; Schulze, 2019).

Commencing in Britain in 1760 the First Industrial Revolution (1IR) was characterised by the invention of the steam engine which allowed for the mechanisation of a significant amount of work (Pomeranz, 2000; Xing & Marwala, 2017). The creation of factories to facilitate this mechanisation of work led to the development of urban areas and cities, which initiated rural-urban migration (Marwala, 2020; Moloi & Marwala, 2020; Schulze, 2019). The Second Industrial Revolution (2IR) starting towards the end of the nineteenth century saw the unification of magnetic and electric forces which led to electricity generation and the electric motor. Key innovations of this revolution because of electricity generation and the electric motor were the light bulb, the internal combustion engine and the telephone (Schulze, 2019). These inventions were influential in mass-production industries like steel, oil, and electricity where assembly lines have become dominant in many industries (Chandler, 1990).

The 3IR (the 1960s) also known as the digital revolution was catalysed by inventions in semiconductors, computers and the internet (Marwala, 2020; Schulze, 2019). According to the WEF (2020), automation and tangible value creation introduced by the 3IR transformed the skills required by individuals to participate in the economy. This skills transformation raised questions about the appropriateness of the education system to keep pace with the transformation.

Schwab (2017) argues that the 4IR builds on the digital revolution (3IR). He states that "technologies that have computer hardware, software and networks at their core are not new but in a break away with the third industrial revolution, they are becoming more sophisticated and integrated and are, as a result, transforming societies and the global economy" (Schwab, 2017, p. 12). This assertion is relevant to the differences between the 3IR and the 4IR which at first glance could be viewed as being concerned with similar technologies. Problems in differentiating between the two revolutions include first, that it is a challenge to differentiate between the digital, physical and biological worlds as the differences are decreasing. Second, the pace at which technology is developing in the 4IR makes it difficult to anticipate the long-term implications and transformations it will bring across various sectors (Marwala, 2020; Schulze, 2019).

The question that can be asked is what technologies are involved in the 4IR? These technologies include AI, robotics, and the Internet of Things (IoT) but there is a need to identify the specific technologies which apply to education.

According to Saleh (2019), AI is the development of computer software that completes activities that would be normally completed by human intelligence. It is beneficial to teaching and learning as it provides a fully trained virtual teacher to an individual at any time and place (Hinojo-Lucena et al., 2019). Robots are programmable machines that can execute a sequence of activities independently or semi-independently (Saleh, 2019). According to Aoun (2017), for individuals to remain relevant robot-proof education is needed. In this robot-proof education, there is a shift from the filling up of learners with facts to an education that attunes their creativity to design, discover and generate useful things in society. Aoun (2017) proposes teaching skills to secure a robot-proof education which includes data literacy which is handling the movement of Big Data, technological literacy which involves understanding how technology operates and human literacy which involves communication and design to operate as a human being. According to Kamaruzaman et al. (2019), the IoT is the transmission of data across a network without needing person-to-person or person-to-computer contact. IoT creates educational spaces "with mixed virtual-plus-reality environments for learning intelligently" (David, 2018, p. 5). This has the potential to enrich both learners' and teachers' learning experiences by them having a sense of being there in the environment. Figure 2.1 is a pictorial representation of the four industrial revolutions.

Figure 2.1: A Snapshot of the Four Industrial Revolutions
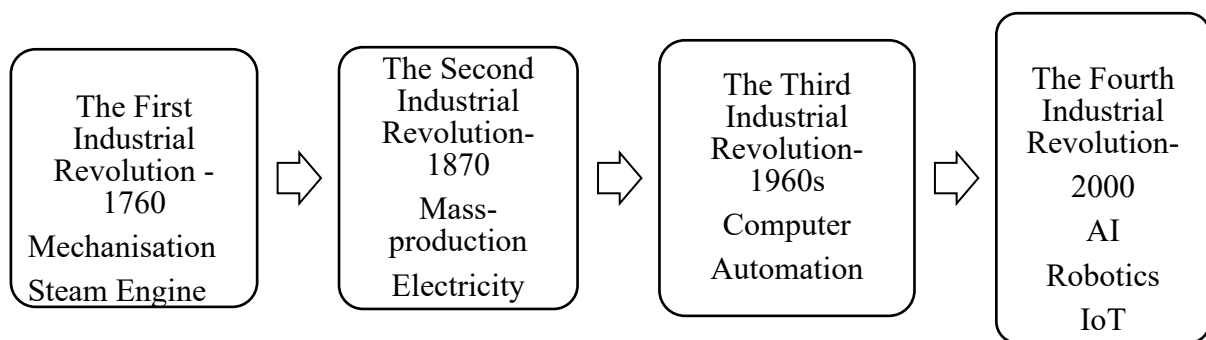
Source: (Adapted from Marwala, 2020)

Past industrial revolutions have influenced the education system. According to the WEF (2020), the requirements of the 1IR and the 2IR chiefly influenced current education which consists of the traditional model of direct learning. This direct learning facilitated the production of a constant supply of skills needed to carry out monotonous jobs. As claimed by Schwab (2016), the 4IR is fundamentally different from previous revolutions as it is driven by

technology which will transform, as never experienced before by humankind, the way we live, work and relate to one another (Schwab, 2015). This suggests that 4IR needs have a different influence on education than the three previous revolutions. It also suggests that indeed the 4IR uniquely influences the education of society due to a radical transformation in how people work as education equips individuals with the necessary skills to work in each society. This influence on education may manifest in a change or modification of teachers' instructional strategies, which were framed in Section 1.1.4, as preparing learners for the needs of the 4IR requires different teaching and learning approaches (Menon & Castrillon, 2019; Webber-Youngman, 2017).

It has been acknowledged the influence of the 4IR manifests in a change, adjustment or modification of the instructional strategies teachers adopt in their teaching practice to facilitate learning. At this juncture, it is necessary to explore the concept of change as it relates to the readiness of teachers to adopt 4IR-based instructional strategies which is key to the current research. The discussion explores the broad or humanistic nature of change, the role of education in society and educational change.

2.2.1 Change

An inevitable characteristic of the human condition is change because an individual is part of a dynamic environment. According to Van de Ven and Poole (1995), a cyclical pattern is responsible for changes in life from birth to death which takes place in a dynamic environment. This suggests that a change to an aspect of an individual's life can be attributed to certain events which influence it. According to Marris (1975), change can be categorised as being imposed or voluntary where personal reflection is common to both. An illustration of the former category is an individual becoming unemployed – such an event will impose a change in their circumstances. In the latter category, an individual might change their lifestyle by incorporating exercise into their daily lives. In both instances, the individual personally reflects on activities to enact the change in their life.

Several dictionaries supply a plethora of phrases and terms for change. These include "make something different", "alter or modify", "replace", "exchange" or "improve" (Cambridge University Press, n.d.; Merriam-Webster, n.d.; Oxford University Press, n.d.a.). Relevant to the current research and the influence of the 4IR is that in-service Life Sciences teachers need to

alter, modify, improve or replace their current instructional strategies to address the aims of the curriculum of South Africa in the 4IR.

2.2.2 Role of Education in Society

Atkin and Black (2003) postulate that education systems and schools play an influential role in addressing serious national challenges such as global economic competitiveness, unemployment and race relations. Expanding on this, Kondakci et al. (2017) suggest that forces originating from economic, political and technological developments in society bring about marked and considerable changes to educational systems and individual schools. These societal developments as forces can be associated with the 4IR. The 4IR will, directly and indirectly, influence society ultimately influencing the education system if taken to its logical conclusion. The influence of this will be evident in the instructional strategies adopted by Life Sciences teachers.

2.2.3 Educational Change

Fullan (2007) writes that education systems need to produce educated global citizens who are continuously learning in an ever-increasingly complex society. Hence, curriculum reform is necessary for individuals to meet the demands of this complex society. These individuals need to be able to work in diverse environments, locally and internationally.

Fullan (2007) expands on educational change by asserting that reform involves much more than people realise. Reform is not limited to the implementation of the latest educational policy but rather involves changing the cultures of districts, schools and classrooms. Change in practice is central to the implementation of curriculum reform. An analysis of the change related to the classroom or at the teacher level follows as this level is concerned with instruction and learning which is involved with change in practice. This analysis applies to the current research as it involves curriculum reform in terms of the adoption of 4IR-based instructional strategies.

At a classroom or teacher level, innovation is an aspect of change. This aspect is multidimensional comprising of three components in the implementation of a new policy (Fullan, 2007). First, as a component of innovation, is the possibility to use new or revised instructional resources namely, curriculum materials or technologies. Second, is the possibility of the use of new teaching approaches which include new instructional strategies and activities.

Third, innovation involves the alteration of beliefs related to pedagogical assumptions and theories underpinning new programmes and policies. Relating innovation to the current research, teachers may need to adjust their pedagogical beliefs to use the new curriculum. This new curriculum may involve the practice of new 4IR-based instructional strategies brought on by the demands or changes which will be apparent in the 4IR educational landscape.

2.2.4 Needs of the 4IR Shaping Instructional Strategies

Education in the 4IR can be explored through the acknowledgement of the needs of the 4IR. An understanding of these needs would assist in identifying the instructional strategies to be adopted by in-service Life Sciences teachers in the 4IR (Section 2.7) as new curricula and teaching approaches will be required if education is to deliver on the needs of society (Menon & Castrillon, 2019).

Webber-Youngman (2017) state that current content taught will be obsolete in the future as the working environment will undergo a major transformation. The issue of employment raised a debate about whether 4IR will create more jobs or result in job losses. This is dependent on the pace of the change determining the rate at which jobs no longer need human engagement. According to Brown-Martin (2017), education and lifelong learning are of vital importance in equipping individuals to meet the needs presented by the 4IR. Interrogating education's role in preparing individuals is explored through the skills or abilities individuals require in the 4IR. These abilities are used to map out the instructional strategies in-service Life Sciences teachers would need to adopt to develop them.

The definition of instructional strategies provided in Section 1.1.3 is revisited to secure comprehensiveness in recognising 4IR-based instructional strategies. This revisit provides more substance to the definition as it includes the opinions of several scholars who have investigated it (Awotua-Efebo, 2007; Marzano, 2003; Obara & Okoh, 2005).

A synthesised definition for instructional strategies is that they are part of a planned instructional process involving measures used by teachers to interactively enhance the communication of the goals to be achieved. They are used to motivate learners and facilitate the teaching and learning experience to secure these goals. Instructional strategies are informed by the needs and interests of the learner, which may be different for each learner. A factor informing the instructional strategies is the environment which includes time, the physical setting and resources.

According to Marzano (2003), instructional strategies do indeed influence learners' achievement. This suggests that deciding on the appropriate instructional strategies informed by elements in the synthesised definition may positively influence learner achievement. Therefore, the applicable 4IR-based instructional strategies are required for learners to achieve success in the 4IR.

According to Gray (2016), 10 skills are required by an individual for the 4IR. These skills include "complex problem-solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence, judgement and decision-making, service orientation, negotiating and cognitive flexibility" (p. 2). Consistent with the skills identified by Gray (2016), the P21CL (2019) asserts that three skills are necessary for the twenty-first century. These are life and career skills, learning and innovation skills, information, media and technology skills, which, to a significant degree, encompass the skills suggested by Gray (2016). Figure 2.2 known as the twenty-first-century 'knowledge-skills rainbow' represents the skills identified by the P21CL (2019).

Figure 2.2: The Twenty-First-Century Knowledge-Skills Rainbow
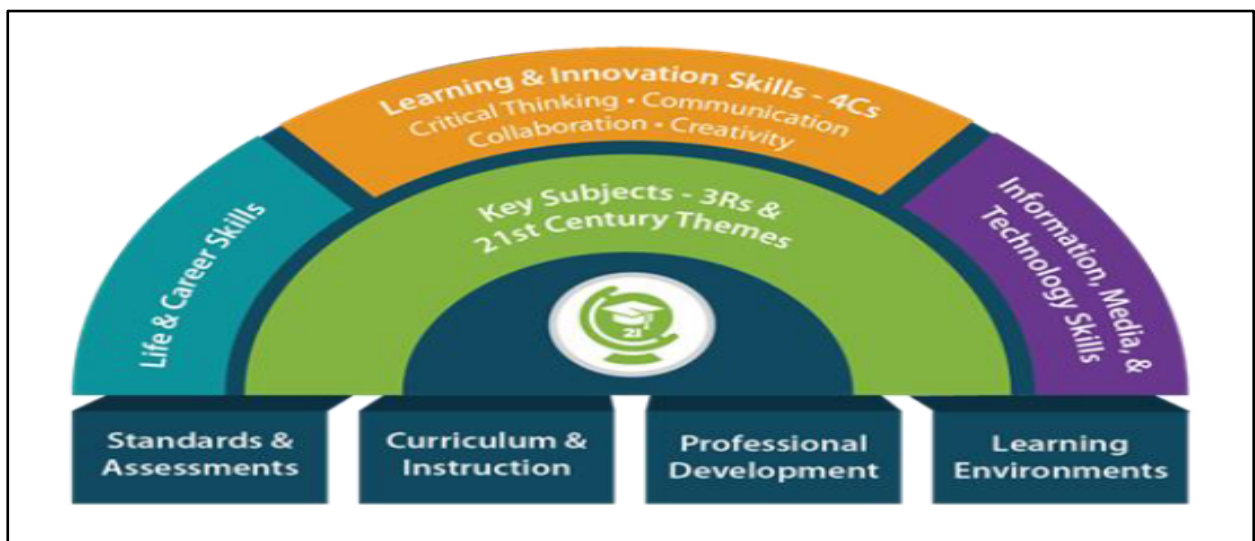
Source: P21CL (2019)

Unpacking the twenty-first-century knowledge-skills rainbow commences with the key subjects and twenty-first-century themes. Key subjects in the twenty-first century include reading, global languages (including English), arts, mathematics, economics, science, social studies, government and the study of the rights and duties of citizenship. In terms of the twenty-first century themes, schools must encourage awareness of academic topics at higher levels by

knitting interdisciplinary themes into the key subjects identified. These themes include "global awareness, financial, economic, business, entrepreneurial literacy, civic, health and environmental literacy" (P21CL, 2019, p. 2).

According to Chrysostomou (2004), the integration of interdisciplinary themes assists learners in making links between subjects, disciplines and areas of knowledge. Proponents of the interdisciplinary approach make compelling arguments: (1) critically engaging with one's discipline through the evaluation of its limitations from an alternative viewpoint holds an educational benefit; (2) contemporary working patterns increasingly demand multi-professional collaboration; and (3) a holistic approach is required to engage with world challenges and technological advancements (Huber, 2002; Jenkins, 2002; Klein, 1990; Maxwell, 2003; Scott; 2002). This suggests that learner success in the 4IR is dependent on the learning of key subjects and themes through interdisciplinary teaching and learning. The value of interweaving interdisciplinary themes can be linked to the deficiencies in teacher competence in facilitating learning in the 4IR in South Africa (Moloi & Mhlanga, 2021). It was found that South Africa's basic education system is not ready for the 4IR. Teachers are still using traditional methods of teaching, which suggests that an interdisciplinary approach has not been adopted. This implies that teachers do not have the skill to adopt an interdisciplinary approach which could be because it is not included in their training.

The P21CL (2019) knowledge-skills rainbow highlights in the twenty-first-century life and career skills that individuals must develop and improve including flexibility and adaptability, initiation and self-direction, social and cross-cultural skills, productivity and accountability and leadership and responsibility. The development of these skills assists in establishing thinking skills, content knowledge, and social and emotional capabilities essential for steering through complex life and work situations encountered in the twenty-first century. Agumba et al. (2019), summarise these life and career skills as leadership qualities, adaptability, social consciousness and the capacity for proactive and productive behaviours in individuals.

Learning and innovation skills are also valuable for steering through complex life and work situations encountered in the twenty-first century (P21CL, 2019). These skills include creativity and innovation, critical thinking and problem-solving, communication and collaboration. Brown and Keep (2018) emphasise individual agility, creativity and lifelong learning which means being flexible and self-directed. Vital to learning and innovative skills is the ability of an individual to traverse diverse subject areas in an integrative manner and for

a teacher to develop cooperative learning that enables learners to learn together collaboratively (Agumba et al., 2019). This further suggests the importance of an interdisciplinary and collaborative approach to teaching and learning. Figure 2.3 represents the aspects of learning and innovation skills which are commonly known as the 4Cs.

Figure 2.3: The Aspects of Learning and Innovation Skills (4Cs)
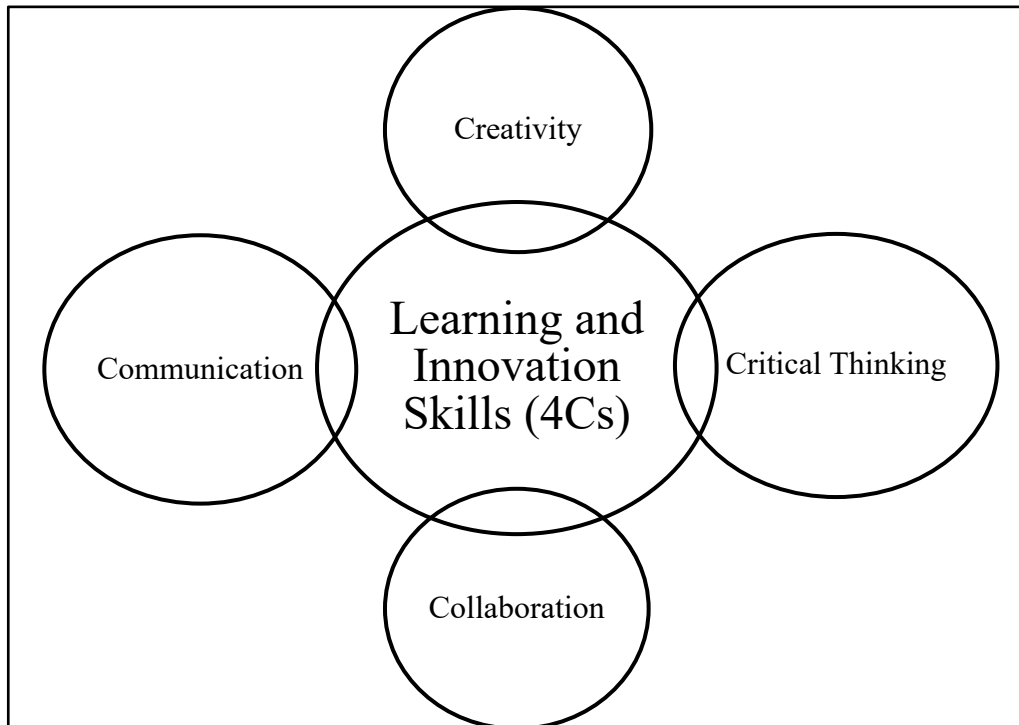
Source: Nababan et al. (2020, p. 220)

Information, media and technology skills are the range of functional and critical thinking skills an individual must exhibit to be an effective citizen (Agumba et al. 2019). These skills are necessary to be able to process an abundance of information, the rapid development in digital technologies and the ability to make contributions through collaboration at an unparalleled level (P21CL, 2019).

The discussion concerned with the twenty-first-century knowledge-skills rainbow highlighted the key subjects and themes including the various aspects of the three skills required. To ensure a holistic understanding of the twenty-first-century knowledge-skills rainbow, an exploration of the aspect of support systems needs to be undertaken and sustained to facilitate the attainment of the skills previously acknowledged. These support systems need to be innovative

to assist learners in creating real-life links to make learning individualised and engaging. According to the P21CL (2019), the support systems required are standards and assessments, curriculum and instruction, professional development and conducive learning environments.

It is worth acknowledging that the skills discussed are also applicable to teachers to be successful in the 4IR. These skills are viewed as competencies teachers must develop or improve on to ensure that learners acquire the skills needed to succeed in the 4IR. For example, according to Nababan et al. (2020), one of the 4Cs is critical thinking. Teachers need to be able to combine learning to enable them to develop this skill in learners. To combine learning, teachers need to be leaders who are flexible, productive and self-directed. These skills are concerned with the life and career skills discussed in this Section.

Since learners need information, media and technology skills, teachers also need to be equipped with the same skills which require a range of competencies. For example, to develop these skills in learners, teachers need to exhibit competencies that include and are not limited to being ICT literate, creative, communicative, flexible and collaborative. In a practical sense, teachers need to know how to use the technology necessary for the activity designed to develop information, media and technology skills in learners. The teacher can be creative by using a range of technologies that would engage the various types of learners making learning personalised. In a communicative sense, the teacher needs to communicate to facilitate the acquisition of such skills. Being flexible and collaborative, the teacher needs to be flexible as the learners might be at a level of competence that was not initially planned for by the teacher, therefore the teacher would need to adjust to the level of the learners. Communication with learners about their competence can foster a collaborative learning process, encouraging active engagement and the sharing of ideas to develop skills.

The WEF (2020) propose a framework for quality education in the 4IR which shifts learning content and experiences toward the needs of the future. Consisting of eight critical characteristics of education on the 4IR, the framework includes the content and experiences that will assist in securing the acquirement of the skills required in the 4IR. Ensuring quality education in the 4IR involves integrating these content and experience characteristics, and acknowledging their significance in fostering skill awareness. Table 2.1 outlines the framework proposed by WEF (2020) for the skills to be developed through the learning content and the experiences that characterise quality education in the 4IR.

Table 2.1: The Characteristics of Quality Education in the 4IR

Skills	Learning content	Learning experience
Global citizenship	Emphasises building awareness concerned with the wider world, sustainability and playing an active role in the global community.	• Personalised and self-paced learning. • Accessible and inclusive learning. • Problem-based and collaborative learning. • Lifelong and student-driven learning.
Innovation and creativity	Develops skills necessary for innovation, including complex problem-solving, analytical thinking, creativity and systems analysis.	
Technology	Grounded in creating digital skills, including programming, digital responsibility and the use of technology.	
Interpersonal	Content that concentrates on interpersonal emotional intelligence, including empathy, cooperation, negotiation, leadership and social awareness.	

Source: (Adapted from WEF, 2020, p. 4)

At first glance, Table 2.1 might seem to have twelve characteristics which contradicts the framework having eight. Closer scrutiny of the table reveals that the headings namely, Skills and Learning Content have been demarcated with the colour green indicating the development of the skills required hinging on the adoption of the applicable content to be included in the 4IR. For example, the development of innovation and creativity skills requires content that develops skills necessary for innovation which includes "complex problem-solving, analytical thinking, creativity and systems analysis" (WEF, 2020, p. 7). Therefore, the first two columns in the table represent four characteristics of the framework proposed by the WEF (2020) as they work in tandem. The learning experiences heading is in a separate colour and represents

the remaining characteristics of the framework. These learning experiences are used at various stages to develop the range of skills found in Table 2.1.

Learning being personalised and self-paced is a shift from learning being standardised. This shift is based on the diverse needs of each learner to empower them to improve at their own pace. Accessible and inclusive learning is a shift from learning being limited to those with access to school buildings to one in which everyone has access to learning and is therefore inclusive.

Problem-based and collaborative learning is a shift from process-based to project and problem-based content delivery, necessitating peer collaboration and more closely reflecting the future of work. Lifelong and student-driven learning is a shift from learning and skilling decreasing over one's lifespan to one where everyone constantly expands on existing skills and acquires new ones based on their individual needs.

The skills required in or for the 4IR acknowledged by Gray (2016), the P21CL (2019) and the WEF (2020) for shifting learning content and experiences toward the needs of the future exhibit commonalities. Identifying these commonalities corroborates literature to ensure comprehensiveness in determining the applicable instructional strategies to adopt in the 4IR. Using the three key skills found in the twenty-first-century knowledge-skills rainbow, Table 2.2 outlines the skills required in the 4IR.

Table 2.2: The Skills Required for the 4IR Identified in the Literature Discussed

Skills	Gray (2016)	P21CL (2019)	WEF (2020)
Career and life	• People management • Coordinating with others • Emotional intelligence • Negotiating • Cognitive flexibility	• Flexibility • Self-direction • Social and cross-cultural skills • Productivity and accountability • Leadership and responsibility	• Interpersonal emotional intelligence i.e., empathy, cooperation, negotiation, leadership and social awareness.

Skills	Gray (2016)	P21CL (2019)	WEF (2020)
Learning and Innovation	• Complex problem-solving • Critical thinking • Creativity	• Creativity and innovation • Critical thinking and problem-solving • Communication • Collaboration	• Complex problem-solving • Analytical thinking • Creativity • Systems analysis.
Information, Media and Technology		• Information literacy • Media literacy • ICT literacy	• Digital skills i.e., programming, digital responsibility and the use of technology.

Table 2.2 shows that there are common skills required to be developed in the 4IR identified in the literature. The common skills inform the determination of 4IR-based instructional strategies to adopt as there is consensus on the skills required and in turn, this enables one to propose instructional strategies that will facilitate the attainment of such skills. An awareness of the skills required informs the decisions of in-service teachers in terms of the instructional strategies to select.

Section 2.2 explored the understanding of the 4IR and its influence on education in terms of introducing a broad overview of the instructional strategies that will develop the skills required in the 4IR. Another component of the current research is the readiness of in-service Life Sciences teachers to adopt these 4IR-based instructional strategies. Section 2.3 identifies the theoretical framework used to frame the readiness of in-service Life Sciences teachers to adopt 4IR-based instructional strategies.

2.3 THE THEORETICAL FRAMEWORK

According to Ngulube et al. (2015), a theoretical framework serves as a blueprint or guide to a study. A theoretical framework serves to provide a foundation for the analysis of generated

data, supplies focus to a study and offers theoretical explanations for a deeper understanding of the phenomenon being explored (Creswell, 2009; Neuman, 2000). Bak (2004) adds that a theoretical framework is vital in ensuring the focus and coherence of a study.

A review of the literature identified theories that form the theoretical framework of the current research. The use of multiple theories is consistent with studies found within the Social Sciences (Ngulube et al., 2015). Two or more theories are used when the phenomenon of a study is multifaceted. This justifies the use of multiple theories in the current research as the phenomenon of the current research involves both the influence of the 4IR on in-service Life Sciences teachers' instructional strategies and their readiness to change. Further justification for using multiple theories is the possibility to enhance the understanding of the phenomenon and the validity and credibility of the findings by triangulation as multiple theories could complement each other (Denzin, 1978; Lincoln & Guba, 1985).

The theories that combine to form the theoretical framework include the RRCM (Holt et al., 2007), the role of attitudes in the readiness for change (Kondakci et al., 2017), the influence of teachers' understanding of 4IR on the readiness for change and the UTAUT (Venkatesh et al., 2003).

2.3.1 Revised Readiness for Change Model

Proposed by Holt et al. (2007), the RRCM applies as the current research is concerned with an individual's readiness to change in terms of adopting 4IR-based instructional strategies. The model contributes findings related to the readiness of in-service Life Sciences to adopt 4IR-based instructional strategies as other aspects of the theoretical framework to be discussed also contribute to them. The RRCM (Holt et al., 2007) illustrated in Figure 2.4 consists of four dimensions namely, appropriateness, management support, self-efficacy and personal valence.

Figure 2.4: The RRCM
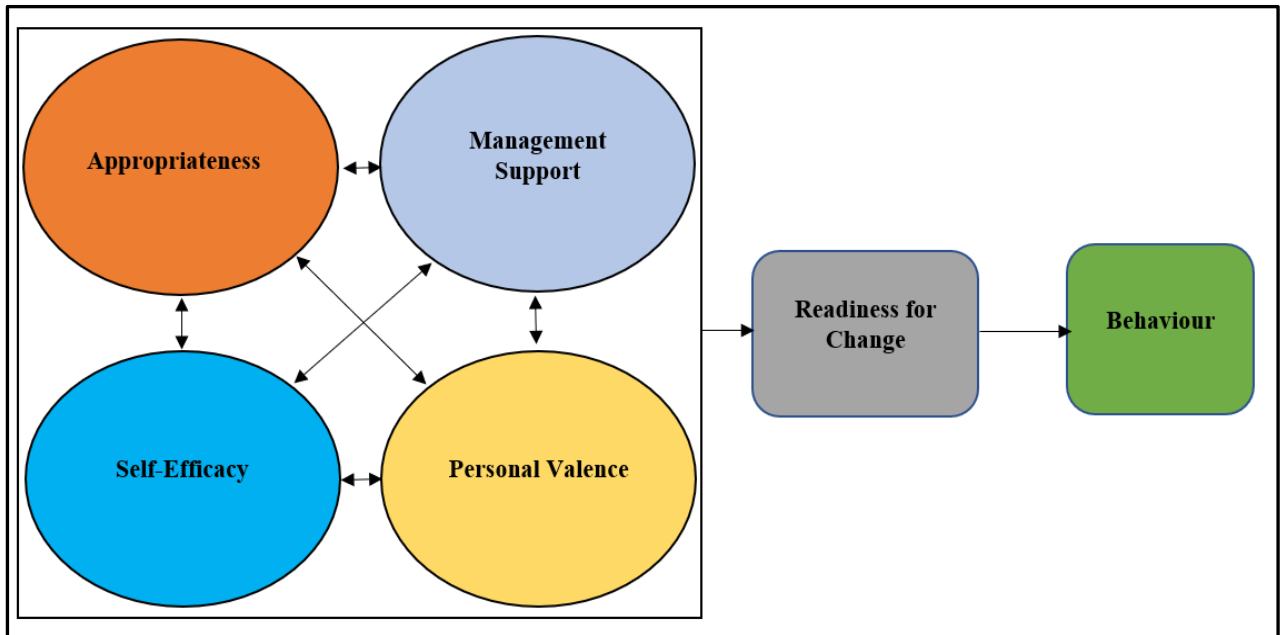
Source: (Adapted from Holt et al., 2007)

2.3.1.1 Appropriateness

The dimension of appropriateness relates to the content and context of the change. Content refers to the difference between the present situation and the envisaged one. The context refers to the implementation of the change. This could include the resources available for the change to be implemented. Teachers may agree that the change is necessary but may disagree with how it will be accomplished (Armenakis & Harris, 2002). If a teacher believes the change is necessary, they are likely to adopt it.

2.3.1.2 Management support

Management support relates to the important role it plays in the process of change. According to Armenakis et al. (1993), managers create a changing environment. This suggests that the implementation of change is dependent on management support. Confidence in the management from prior change initiatives may influence the readiness of teachers to change which influences the adoption of a new behaviour.

2.3.1.3 Self-efficacy

Self-efficacy is personal to individuals and may differ between them. This influences how individuals perceive a coming change. Self-efficacy is important in creating readiness for change, as motivation for change is influenced by the individual (Armenakis et al., 1993; Armenakis & Harris, 2002; Holt et al., 2007). According to Gist and Mitchell (1992), self-efficacy is an individual's belief in their ability to perform a given activity. Individuals avoid activities that they perceive to be beyond their skill set (Bandura, 1997). For example, some teachers may not have the necessary competence to implement 4IR-based instructional strategies and therefore will not be motivated to do so. Tschannen-Moran et al. (1998) state that self-efficacy "affects the effort they invest in teaching, the goals they set and their level of aspiration" (p. 783). Teachers with low self-efficacy have more difficulty in teaching, more stress, less resilience when things go not to plan and low levels of job satisfaction (Betoret, 2006; Skaalvik & Skaalvik, 2014; Tschannen-Moran et al., 1998).

Related to self-efficacy is the concept of perceived behavioural control found in the theory of planned behaviour (Ajzen, 2005). The theory of planned behaviour is informed by the assumption that individuals act rationally, considering the existing information and directly or indirectly reflecting on the consequences of their actions. Perceived behavioural control is how capable an individual feels to perform a specialised action within their setting which includes time, classroom settings and resources.

2.3.1.4 Personal valence

Personal valence refers to an individual's perception that the change is beneficial to him or her. According to Holt et al. (2007), it is dependent on what the individual considers important to them. Personal benefit is not only confined to pay but people also resist the loss of comfort associated with the loss of status. This suggests that individual teachers might resist the change which speaks to their readiness for it due to them being uncomfortable with it.

Teacher readiness for the adoption of 4IR-based instructional strategies is partly dependent on the four dimensions outlined in the RRCM (Holt et al., 2007). Teachers who think that the change is appropriate, believe the change will be supported by management, are confident that they will be able to change successfully, and that there will be something in it for them to develop a positive attitude or belief towards the change, all of which influence their behaviour positively in terms of the adoption of 4IR-based instructional strategies.

This Section explored the RRCM (Holt et al., 2007) and recognised that it contributes to an individual's attitude towards change. In the interest of coherence in the explanation of the theoretical framework, the concept of attitude is explored in the next Section as it is referred to in subsequent sections explaining the theoretical framework.

2.3.2 Influence of Attitudes on the Readiness for Change

According to Ajzen (1991), an attitude, a concept of the theory of planned behaviour, relates to the extent to which an individual approves or disapproves of an action. Ajzen (1993) adds that an individual tends to respond to a specific event in their world and acknowledges that although an attitude is difficult to observe as it is in the person's mind, it can be measured through the response of an individual to the specific event. This reaction could be positive or negative to the event (Ajzen, 1993; de Souza Barros & Elia, 1998). According to de Souza Barros and Elia (1998), an attitude is an individual or rational thought for the planning of an activity where experience shapes a reaction to stimuli. Cherry (2019) recognises that an attitude is dependent on experiences and environment; therefore, an attitude is dynamic and can also be changed as new experiences and environments are experienced.

Contextualising these definitions to teaching and learning is that an attitude is measurable and personal and is influenced by experiences shaping the responses or activities (positive or negative) of the teacher. These responses or activities of the teacher can be regarded as their teaching practice consisting of instructional strategies.

Clegg and Walsh (2004) argue that ignoring the role of teachers in change limits the effectiveness of change interventions. This suggests that teacher readiness for change is important as it is part of the teachers' makeup which influences the role of teachers. Teacher readiness includes the state of their attitudes towards change. Cockburn (2005) states that to effect successful change it needs to be embraced. Chow (2013) further argues that a top-down approach is not ideal for educational change but rather teachers need to own the change through the consideration of contextual conditions. According to Armenakis and Bedeian (1999), management must determine the critical context, process and outcome factors that garner positive attitudes towards change.

Kondakci et al. (2017) in unpacking the role of teacher attitudes in change identified that background, context, job outcomes and process are concepts that impact a teacher's readiness for change to varying degrees. According to Kondakci et al. (2017), the readiness to change is

an attitude consisting of an array of forces, namely, job outcome forces, trust in the principal and colleagues, and the role of process factors that support or resist change. These forces in part are used to determine their readiness for change. This suggests that teachers' attitudes are an important variable in determining if teachers are ready for change. The forces that shape an individual's attitude concerned with their readiness for change are discussed below.

2.3.3 Job Outcome Forces

Job outcome forces are how an individual perceives their work experience in terms of job satisfaction and workload. According to Locke (1976), job satisfaction is a feeling resulting from a person reflecting on their work experience and is expressed as a positive or negative attitude held towards their work. Jex and Britt (2008) define productive work practices as "employee behaviours that contribute positively to the goals and objectives of the organisation" (p. 96) consisting of factors that include innovation, job performance and job commitment. According to Spector (1997), job satisfaction is positively linked with job participation, positive attitude and self-esteem. The above suggests that job outcomes which include job satisfaction influence the manifestation of a positive attitude towards change.

The workload is a teacher's perception of whether they can complete their activities in the allocated time. This reflection involves factors such as work pace, the number of activities and time pressures where there is a correlation to burnout, lowered job satisfaction and turnover (Hargreaves, 2003). Reflection on these factors influences teachers' views of change. Teachers may not have the time to allow them to recover from the multiple tasks and take advantage of personal development interventions. The lack of time from 'role overload' is aligned with a teacher's readiness to change as they do not have the time to improve their competencies to effect change (Rafferty & Jimmieson, 2010). According to Rafferty and Simons (2006), confidence in personal abilities is closely aligned with change. This suggests that the ability to cope with the workload and trust in their abilities is likely to foster a positive attitude to change.

The job satisfaction within the job outcomes aligns with the personal valence dimension highlighted in the RRCM (Holt et al., 2007) as detailed in Section 2.3.1. This connection emphasises that an individual's satisfaction with their work is dependent on their perception of its benefits. Similarly, the workload aspect is linked to the self-efficacy dimension of the RRCM (Holt et al., 2007), signifying that individuals assess their ability to complete tasks within the given time based on their perceived capability to execute these activities. The links

identified between the job outcomes forces and other aspects of the theoretical framework are in line with the view that the use of multiple theories in a study enhances triangulation (Denzin, 1978).

2.3.4 Trust in Principal and Colleagues

Mayer et al. (1995) write that 'trust' is concerned with an individual voluntarily being open to another person's influence and expectations. According to Kondakci et al. (2017), trust in the principal is the view that the change is informed by a rational need and not a personal desire of management. The principal is generally responsible for the interventions implemented by teachers as they are viewed as the designers of change. Trust in the principal increases the belief that the change will benefit the school and that the school can accomplish the change (Sekerka et al., 2009). Teachers trust that the principal will disseminate information on progress, be open to participative change and support them. Shah (2010) adds that just practices by the principal contribute to a trusting environment which is important to the teachers' readiness to change. Trust in the principal is related to the dimension of management support of the RRCM (Holt et al., 2007) discussed in Section 2.3.1. Confidence in management to implement the change due to their support will garner trust in the principal. This again enhances triangulation securing the credibility of findings (Denzin, 1978; Lincoln & Guba, 1985).

Tschannen-Moran (2001) writes that trust in colleagues is an important component of a trusted environment in schools and is a source of productive practices such as activity performance, collaboration, group fulfilment and commitment. According to Desplaces (2005), believing that colleagues are supportive of change can positively alter an individual's attitude towards change. This suggests that the readiness for change can be positive when change is viewed as social interaction.

2.3.5 Role of Process Factors

According to Armenakis and Bedeian (1999), process factors are "actions undertaken during the enactment of an intended change" (p. 295). These actions include social interactions, participative management and the distribution of knowledge. Group dynamics included in these actions play a role in forming positive attitudes towards change (Peach et al., 2005).

According to Eby et al. (2000), social interaction contributes to communicating that the organisation can achieve change. It allows for individuals to merge their experiences related to

procedures and actions which encourages a consensual understanding of actions and key characteristics of the workplace (Kozlowski & Klein, 2000).

Another process factor is participative management which influences the promotion of a positive attitude towards change (Terry & Callan, 1997). Participating in the change process enables individuals to feel that they are effecting the change by developing a feeling of acknowledgement and appreciation (Armenakis et al., 1993). Wanberg and Banas (2000) add that an outcome of participative management is an increase in employee commitment as participation promotes the belief that the change will bring about positive results. The consequence of participation is clarity through the elimination of ambiguity (Rafferty & Simons, 2006).

The final factor influencing readiness for change is knowledge sharing, which pertains to an organisation's capacity to disseminate knowledge effectively to facilitate its integration throughout the organisation (Kogut & Zander, 1996). Higgins (1996) comments that attitudes develop and are informed by the nature of the information provided.

Aspects of knowledge sharing include specifying the aims of the change and clarifying potential outcomes; serving as feedback and improving efforts to complete certain activities; and eliminating reliance on irrelevant information sources. Lastly, knowledge sharing is likely to promote a common understanding of the need for change. Considering the comments by Higgins (1996) and the aspects of knowledge sharing suggests that it is an important aspect of developing a positive attitude toward change. A positive attitude is comprised of anticipation, effectiveness, optimism and flexibility.

The role of process forces is related to the dimension of management support found in the RRCM (Holt et al., 2007) discussed in Section 2.3.1. Management can initiate and sustain a participative management approach and knowledge sharing. By being included in effecting the change, individuals can feel that they have the support of management where trust is formed in the relationship. This further enhances triangulation due to the use of multiple theories in a theoretical framework (Denzin, 1978).

The process factor of knowledge sharing discussed in this Section leads to a discussion concerned with the understanding of the 4IR influencing an individual's readiness for change. Understanding a topic or concept contributes to an attitude and therefore forms part of the

theoretical framework. Including the influence of the understanding of a topic or concept on an attitude supports the comprehensiveness of the theoretical framework.

2.3.6 Influence of 4IR Understandings on the Readiness for Change

Understanding that the needs of the 4IR are different from the other industrial revolutions discussed in Section 2.2 is the acknowledgement that education in the 4IR is, therefore, different. According to Junid et al. (2019), these differences are concerned with learning spaces, teaching methods, a more vibrant curriculum and the use of the newest technology.

Achieving the aims of this new education system and therefore the needs of the 4IR requires schools to have qualified, knowledgeable teachers who are capable of being change agents for learners by assisting them in processing the knowledge acquired and applying it (Wesch, 2008). Therefore, the level of teacher understanding of the 4IR is explored as the teachers, being the agents of change, are responsible for facilitating the learning of learners. Exploring the understanding of the 4IR contributes to determining the readiness of teachers to adopt the changes suggested by Junid et al. (2019) which includes their instructional strategies.

The relevance of exploring teacher understanding concerning teachers' readiness to adopt 4IR-based instructional strategies is informed by the factors that hindered the implementation of past educational change identified in Sections 1.2.3-1.2.4. The under-preparedness of teachers to grasp the intricacies of implementing was due to the use of extremely obscure and complicated language. This suggests that teachers were not ready to implement the curriculum due to their lack of understanding. In terms of understanding the 4IR, Romy et al. (2019) found that pre-service teachers had a moderate level of understanding and need to improve this. By including attitudes which contribute to an individual's readiness to change in the theoretical framework, the understanding of the phenomenon impacts will be enhanced.

According to van Manen (1977), knowledge creation is dependent on an individual's educational experiences. An experience is one's intimate involvement in something (Collins, 2006). These definitions are relevant as the teachers personally participate in the Life Sciences curriculum which includes instructional strategies. Therefore, their understanding can be attributed to their previous and current educational experiences. This is in line with Kondakci et al. (2017) who found that teachers' backgrounds and experiences influence teachers' readiness for change. This suggests that their understanding impacts attitudes which influence their teaching practice that is subject to change.

In contextualising teachers' understandings of the 4IR and 4IR-based instructional strategies to the current research, a discussion on the factors which contribute to understanding the value of and the impact the 4IR has on teachers' teaching practice follows. The discussion draws on previous work related to discourses around two topics in science education which have received much attention over the last few decades. These topics are Indigenous Knowledge Systems (IKS) and the Nature of Science (NOS). Engagement with the findings related to teacher understanding of these topics in science education is applied to explore teachers' understanding of the 4IR.

Naidoo (2010), in exploring teachers' understanding and implementation of policy concerned with IKS, states that several sources which are experiences informed their understanding of IKS. These sources included their biographies, university courses, parents, grandparents, elders, values, cultural backgrounds and world views that shaped the different approaches implemented by the teachers in their teaching practices. This suggests that individuals have understandings of the 4IR that influence their teaching practice differently.

According to Singh (1998), a correlation exists between teachers' understanding of the NOS and their teaching practice. The way teachers teach is influenced by the way they were taught, the learning materials used, the curriculum used, their teacher training and past beliefs about science. These aspects influence their comprehension of the NOS shaping their teaching practice. This suggests that the teaching philosophy of the 4IR held by the participants in the current research informed by past experiences will influence their teaching practice. According to Avelino and Ismail (2022), teachers' levels of understanding of the 4IR and readiness influence the integration of 4IR technologies in their teaching practices.

The understanding of a topic also shapes a teacher's attitude towards it. Stemming from experiences which shape understanding of a topic that could be limited, resulting in a lack of confidence about it, a negative attitude influencing learning may develop (de Souza Barros & Elia, 1998). This suggests that teachers who have no or limited understanding of the 4IR will have a negative attitude towards it due to a lack of confidence, influencing their teaching practice negatively. Brickhouse (1990) found that teachers' attitudes about the NOS influenced their classroom behaviour. This influence of their attitudes was observed in their organisation of practical work which involved how demonstrations were used in the classroom. These demonstrations are instructional strategies that facilitate learning. This suggests that indeed teachers' attitudes influence the adoption of instructional strategies. From the discussion, a

relationship between experiences, understandings and attitudes about a topic and teaching practice was unearthed. Figure 2.5 represents this relationship.

Figure 2.5: The Relationship between Experiences, Understandings, Attitudes and Teaching Practice
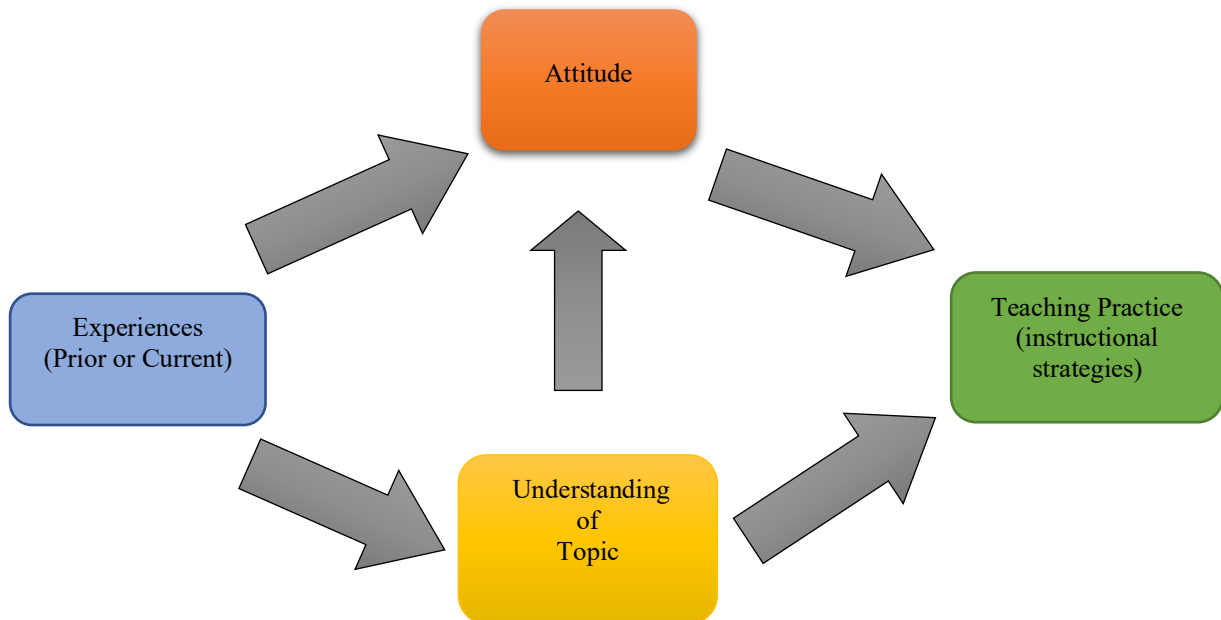
The arrows in Figure 2.5 represent the influence that an aspect has on the others in this relationship. To contextualise this in the current research, the level of teachers' experience in or of the 4IR influences their understanding and attitudes towards it which influences the adoption of 4IR-based instructional strategies in their teaching practices.

According to Koopman (2022), teachers have a very basic understanding of the 4IR technology that would enhance their teaching as they often rely only on cell phones to enhance their teaching. He argues that this understanding is based on CAPS and the 3IR where the emphasis is on the use of mobile devices and the internet. The definition supplied by Schwab (2016) of the 4IR which includes advancements in innovative robotics and AI corroborates this finding of teachers having a very basic understanding of the 4IR as these forms of technologies were not mentioned. Considering the relationship between teachers' understandings of a concept, their attitudes and their teaching practice suggests that teachers with a very basic understanding of the 4IR will not be well-positioned to adopt 4IR-based instructional strategies.

The reliance on cell phones does not, however, detract from the benefits of using them. According to Koopman (2022), recently smart phones with more social media applications such as Facebook, WhatsApp and Blogs have been used. Beastly and Peters (2013) state that "these platforms become the basis for social (co-) production where individuals and communities share, co-produce and co-create, code and new e-infrastructure and portals" (p. 4). According to Nxumalo-Dlamini and Graigher (2019), computer-based simulations, which can be disseminated via a cell phone using social media applications, can be effective in teaching science. This effectiveness stems from teachers having positive attitudes towards computer-based simulations which rubs off on their learners.

According to Ma and Wang (2017), the benefits of mobile technologies include that they provide visible images of objects and scientific procedures, offering more flexibility for learning and supporting interactive collaborations both in and outside the classroom. Bohloko et al. (2019) found that YouTube as a teaching resource was popular and that it improved learner performance.

2.3.7 The Unified Theory of Acceptance and Use of Technology

According to Buckenmeyer (2010), computer technology can improve teaching and learning through the re-creation of complicated, time-consuming and hazardous scenarios as it provides opportunities that were not available before. Schwab (2015, 2016) views the 4IR as the fusing of a variety of technologies that blurs the lines between physical, digital and biological entities. According to Lee et al. (2018) in defining the 4IR state that consideration should be given to the integration of both technical and institutional innovations which are important structural components. A relationship exists between humans and technology which increases functional efficiency in teaching while promoting socioeconomic and environmental achievements. This suggests that the use of technology is intrinsic to teaching and learning in the 4IR and therefore the instructional strategies adopted.

There has been a reluctance by the education sector to accept technology to aid teaching and learning even though technological innovations have improved (Tymon, 2013). According to Kondakci et al. (2017), the use of technology has been limited in teaching and learning where teaching is aided by a personal computer and providing electronic teaching resources. The use of technology in this way does not encompass the fundamentals of the use of technology in the 4IR which promotes a learner-centred methodology to improve the learning experience.

However, in recent times the use of technologies in the education sector has increased (Hashim, 2018).

The realisation that technology has a role in teaching and learning in the 4IR as its use has escalated but that teachers are not using it to its full potential in securing a learner-centred teaching environment or experience leads one to ask what the readiness of teachers to infuse technology into their teaching practice. This is aligned with the current research as it explores teacher readiness to adopt 4IR-based instructional strategies that involve the use of technology. To establish the readiness of teachers to use technology in their teaching practices, the UTAUT (Venkatesh et al., 2003) is used.

The UTAUT (Venkatesh et al., 2003) consists of four factors used to determine the intention to use technology. These four factors are performance expectancy, effort expectancy, social influence and facilitating conditions. Added to the factors that determine individuals' readiness to embrace technology are moderating factors (gender, age, experience and voluntariness of use) that moderate the relations between the factors and the intention to use behaviour. Figure 2.6 is a representation of the UTAUT (Venkatesh et al., 2003).

Figure 2.6: The UTAUT
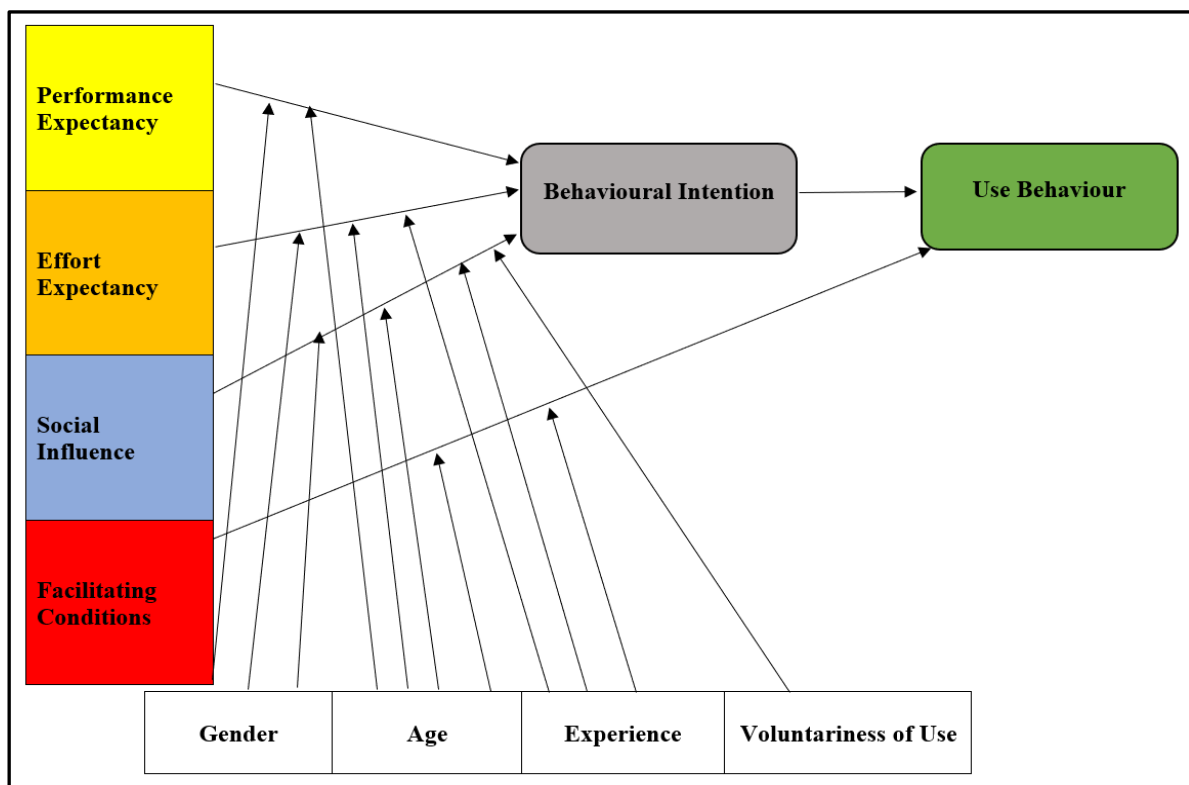
Source: (Adapted from Venkatesh et al., 2003)

2.3.7.1 Performance expectancy

Performance expectancy is "the degree to which an individual believes that using the system will help him or her to attain gains in job performance" (Venkatesh et al., 2003, p. 447). In terms of the current research, performance expectancy relates to technology improving the performance of teachers. A related aspect to performance expectancy, as defined by Dwivedi et al. (2017), is performance usefulness, indicating that individuals are more inclined to adopt a new behaviour if they consider that it improves their job performance. This improvement could include teachers changing their teaching practice to a learner-centred methodology. Koopman (2022) found that teachers showed hesitation in integrating technology into their lessons if they perceived no advantages for themselves and their students in using it to enhance lesson delivery. Concerning the moderating factors, Venkatesh et al. (2003) write that performance expectancy may vary in terms of the age and gender of individuals.

The factor of performance expectancy can be related to the dimension of the personal valence of the RRCM (Holt et al., 2007) discussed in Section 2.3.1 and job satisfaction in Section 2.3.3 which explored the influence of attitudes on the readiness for change. The relatedness is linked to an individual's belief that a new activity will be beneficial to them. Individuals could believe that the use of technology improves their classroom performance and that this improvement is personally beneficial to them. This is in line with the use of multiple theories in the theoretical framework enhancing triangulation (Denzin, 1978).

2.3.7.2 Effort expectancy

Effort expectancy is "the degree of ease associated with the use of the system" (Venkatesh et al., 2003, p. 450). Koopman (2022) found that contributing to the reluctance of teachers to use technology in their classrooms was their belief that using technology would require a lot of effort to fully grasp the use of technology effectively. Linked to effort expectancy in terms of the skills level of teachers determines the ease they can use 4IR technology. Razak et al. (2018) found that teachers need to improve their technological skills through professional development interventions. This indicates that there is a gap between the current skill levels and the proficiency required for using 4IR technology. Concerning the moderating factors, effort expectancy is stronger for younger women at the early stages of experience (Venkatesh et al., 2003).

The factor of effort expectancy can be related to the dimension of self-efficacy of the RRCM (Holt et al., 2007) discussed in Section 2.3.1 and workload in Section 2.3.3 which explored the influence of attitudes on the readiness for change. The relatedness is that, in reflecting on how they can complete their activities in the allocated time, individuals will consider if they can perform the new activity. This is in line with the view that the use of multiple theories in a theoretical framework enhances triangulation (Denzin, 1978).

2.3.7.3 Social influence

Social influence in the UTAUT is "the degree to which an individual perceives that important others believe he or she should use the new system" (Venkatesh et al., 2003, p. 451). According to Dwivedi et al. (2017), these "important others" include curriculum planners and policymakers. Women are inclined to have an increased sensitivity to the views of others; hence, the impact of social influence is greater for women while they are establishing their views around the use of new technology. As experience increases, social influence will decline, especially in the older age groups. Koopman (2022) found that teachers' reluctance to use technology is intensified by policies which are in place that call for the use of technology. Related to social influence is the concept of subjective norms found in the theory of planned behaviour (Ajzen, 2005). Subjective norms are deemed to be social pressures which include the apparent expectations of others and the degree to which these expectations are valued by the individual.

The social influence factor of the UTAUT (Venkatesh et al., 2003) is related to trust in colleagues discussed in Section 2.3.4 which explored the influence of attitudes on the readiness for change. A high degree of trust in colleagues can influence an individual to adopt a new activity if trusted colleagues adopt it. This again enhances the validity of the current research in terms of the use of multiple theories in the theoretical framework (Denzin, 1978).

2.3.7.4 Facilitating conditions

The facilitating conditions as a factor of the UTAUT is "the degree to which an individual believes that an organisational and technical infrastructure exists to support the use of the system" (Venkatesh et al., 2003, p. 453). This involves the availability of the infrastructure that includes the technology teachers need to plan and deliver lessons effectively with consideration given to the skills required in the 4IR (Dwivedi et al., 2017). Examples of this infrastructure include a computer laboratory, Wi-Fi connectivity and mobile devices. Koopman (2022) found

that teachers' reluctance to use technology is due to the lack of availability of resources in the surrounding area of the school. Age and experience are moderating factors that impact the relationships between facilitating conditions and the intention to use. As experience increases the impact of these moderating factors is stronger, especially in the older ages.

The UTAUT (Venkatesh et al., 2003) suggests that teachers' readiness to adopt 4IR-based instructional strategies, which incorporate technology, relies on several factors. Teachers are inclined to use technology if they perceive it as beneficial for their job performance, feel confident in using it, are influenced by their peers, have access to necessary resources at school and maintain a positive attitude toward integrating technology into 4IR-based instructional strategies. Figure 2.7 merges the theories discussed in Section 2.3 to represent the theoretical framework of the current research.

Figure 2.7: The Theoretical Framework
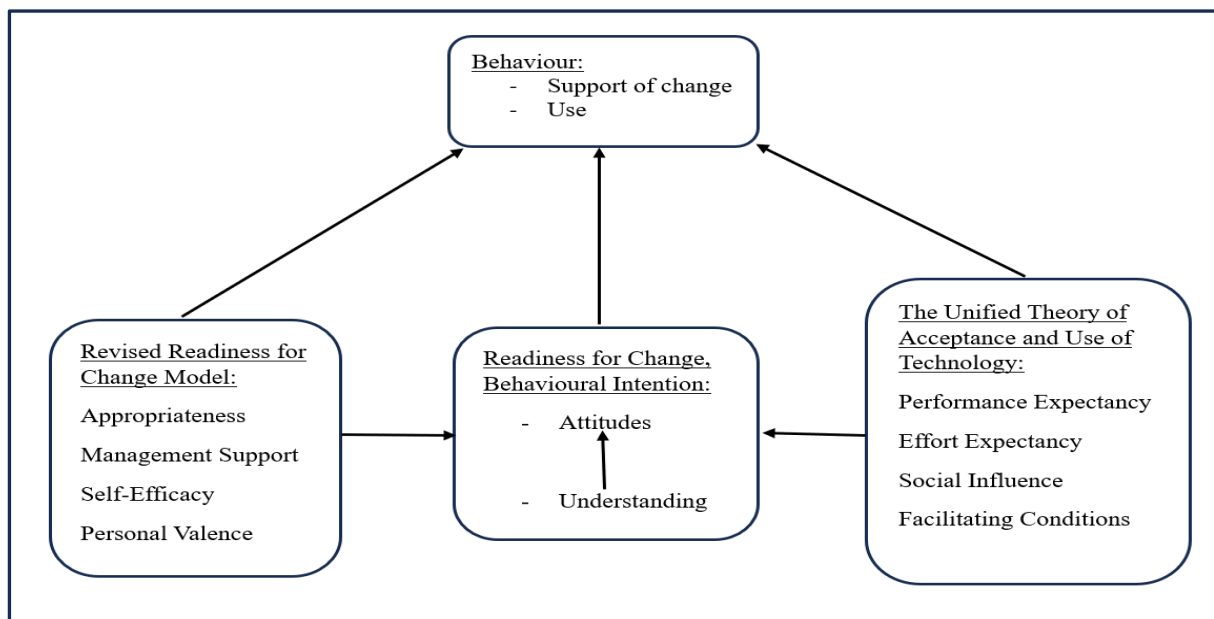
To the left of the lower middle block in Figure 2.7 is a representation of the RRCM (Holt et al., 2007). It identifies an interaction between the four dimensions contributing to an individual's readiness for change. To the right of the lower middle block is a representation of the UTAUT (Venkatesh et al., 2003). It shows the four factors that are used to determine an individual's intention to use the behaviour (technology). The lower middle block shows that readiness to use and behavioural intention depends on the understanding and attitude of an individual which is dependent on an individual's experiences. The use or non-use of the

behaviour (upper block) is dependent on the impact of the dimensions (Holt et al., 2007), understandings, attitudes and factors (Venkatesh et al., 2003) explored.

The theories presented in this Section form the theoretical framework that contributes to determining the readiness of in-service Life Sciences teachers to adopt 4IR-based instructional strategies.

2.4 CURRICULUM

Aspects relevant to curriculum are applied to the current research as instructional strategies are integral to them. These aspects include the ideological nature of a curriculum and the way it can be represented and effectively implemented. Its effective implementation is relevant as the term 'adopt' in the title of the current research implies 'to implement'.

A myriad of definitions has been proposed for the term 'curriculum'. According to the seminal work of van den Akker et al. (2009), definitions of the curriculum are either narrow or broad which is often a source of confusion. The word 'curriculum' is derived from the Latin verb *currere* which means 'to run' and as a noun implies a 'course' and a 'vehicle'. According to Taba (1962), a curriculum represents a 'plan for learning' which is a linear view of curriculum requiring a series of steps (Ornstein & Hunkins, 2018). Wiles and Bondi (2014) posit these steps as a developmental process that "(1) identifies a philosophy; (2) assesses student ability; (3) considers possible methods of instruction; (4) implements strategies; (5) selects assessment devices; and (6) is continually adjusted" (p. 142). Rao (2010) views a curriculum as a mass of information comprised of content where education is perceived as the use of ways that most effectively transmit this information to learners. This definition only includes the transmission of knowledge which is evidence of a narrow view. These definitions include possible methods of instruction and the implementation of strategies, therefore identifying that the curriculum includes the implementation of instructional strategies which is relevant to the current research. Defined in a broad sense, a curriculum encompasses the learners' experiences (Ornstein & Hunkins, 2018). These experiences often guided by teachers can take place both in and outside of school. The next Section explores how instructional strategies form part of the curriculum.

2.4.1 Ideology of a Curriculum

Educational institutions, as per Apple (2004), seek to disseminate information and ideological principles, which are crucial in maintaining the current economic, political and cultural circumstances. The curriculum's role in preserving the status quo can be viewed as a means of societal control. According to Apple (2004),

> education in general, and the everyday meanings of curriculum in schools in particular, were seen as essential elements in the preservation of existing social privilege, interests and knowledge, which were the prerogatives of one element of the population, maintained at the expense of the less powerful group. (p. 45)

The curriculum implemented before democracy in South Africa is an example of a curriculum aimed at societal control maintained by the educational policies implemented by the apartheid government. According to Jansen (1999), education before democracy was "racist, Euro-centred, sexist, authoritarian, prescriptive, unchanging, context blind and discriminatory" (p. 4). Central to this education was the separation of races preparing them for distinct functions in society. This was facilitated by organising education with distinct education departments for each race which used distinctive curricula.

Christian National Education, an education system implemented by the South African apartheid government, aimed to assign specific societal roles to different races, upholding white privilege through a "divide and rule" approach (Pillay, 2006). The curriculum's evident bias under apartheid education displayed its injustices. Whether explicit or indirect, this bias was manifested in the curriculum. For instance, previous South African curricula, as shown in Sections 1.2.3 and 1.2.4, encompassed factors like inadequate training and resources. These elements may not have been explicitly intended during implementation but underscore the implicit bias within the curriculum. Learners engaging with teachers possessing adequate skills and resources benefit more, reflecting this implicit partiality. Ideology thus influences how education is structured and delivered and the content that is prioritised within the curriculum. For example, colonialisation deprived individuals of aspects which formed their identities through explicit and hidden mechanisms resulting in a loss of identity. These aspects included the loss of culture, land, opinion, pride and customary practices because the colonisers arrogantly believed they had a divine right to subjugate, abuse and pillage (Durie, 2004).

The question then is to ask, what is the ideology of the curriculum which includes instructional strategies that respond to the influence of the 4IR in South Africa? Will they retain or possibly perpetuate the status quo that has a disparity in the way education is delivered to learners? Some learners experience better quality education than others. This disparity in many instances influences an individual's progress through life which in a sense controls individuals in South African society.

The intended (formal) curriculum provides direction to teachers on the knowledge, values and skills learners must acquire (Hoadley & Jansen, 2013). Wiles and Bondi (2014) comment that a curriculum identifies possible instructional strategies that are continually adjusted. Combining these two aspects of a curriculum, i.e., the intended (formal) curriculum and instructional strategies that can be adjusted can be linked to this discussion of the ideology of a curriculum. Reflecting on this leads to the assertion that 4IR gives rise to an ideology that influences the knowledge and instructional strategies of a curriculum to establish and maintain a new status quo in society.

2.4.2 Curriculum Representation

The curricular spider web (Figure 2.8) consisting of ten components represents a curriculum where each component is an aspect of learning that individuals will be exposed to (van den Akker et al., 2009). A spider web is flexible with different connected strands – a useful metaphor for describing a curriculum. The symmetry of a spider web is also important – in a curriculum, equal attention needs to be paid to each component if its implementation is to succeed. A break in the spider web could cause the entire structure to collapse, just as a disruption in any part of the curriculum could affect its overall effectiveness. Figure 2.8 represents the curricular spider web as a cluster of bubbles.

Figure 2.8: The Curricular Spider Web
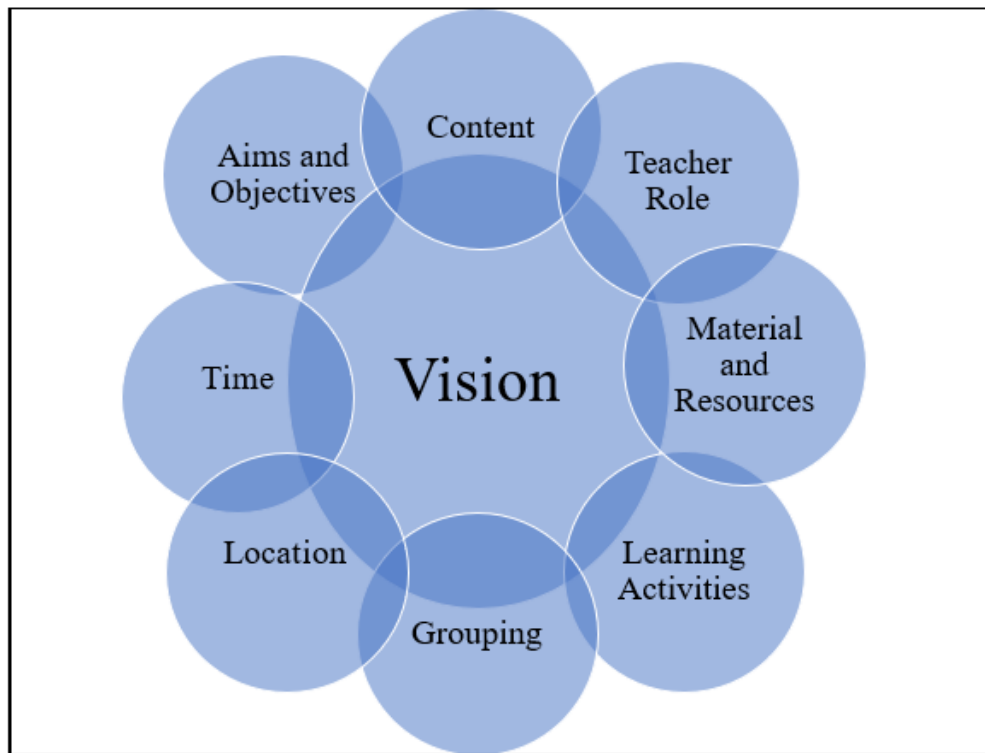
Source: (Adapted from van den Akker et al., 2009, p. 11)

Adapted from the spider web with relevance to its vulnerable nature is the analogy of a cluster of bubbles that are produced from a bubble blower. If an individual does not take care of the bubbles with equal attention, the whole cluster of bubbles will be affected. This suggests that if instructional strategies are not given the necessary attention in the 4IR, other components of its curriculum are affected leading to unsuccessful implementation.

This Section defined a curriculum in which instructional strategies are an integral part. It went on to discuss the ideological nature of a curriculum and the representation of a curriculum in the form of a spider web. An application of this is that a curriculum has a distinct ideology or vision which influences the instructional strategies employed by teachers as they are tools used to implement the ideology. For example, if the ideology or vision of a curriculum is to produce learners who are problem solvers, then the teacher will assess the learners' ability to solve problems to determine which instructional strategy is appropriate. After the teacher has determined and implemented the appropriate instructional strategy to achieve the ideology of the curriculum, upon the teacher's reflection on the instructional strategy implemented, the teacher could decide to adjust or change it. This is relevant to the current research since the

4IR's influence on education may alter the curriculum's ideology or vision, thereby affecting how teachers use instructional strategies based on their adaptability to these changes.

2.5 CURRICULUM IMPLEMENTATION

The implementation of a curriculum is a critical aspect often neglected (Hoadley & Jansen, 2009; Jansen, 2002; Yang, 2013). Morris and Adamson (2010) add that the implementation of a curriculum is often regarded by teachers as problematic as it is multifaceted, occasionally symbolic, politically orientated and contrary to the status quo. According to O'Sullivan (2002), this view contributes to curriculum implementation being regarded as a Black Box as there is a lack of correspondence between the intended curriculum and the implemented curriculum. Ornstein and Hunkins (2014) ascribe the difficulty in curriculum implementation to the process of verifying what has been implemented compared to what is intended.

Defining curriculum implementation has proven difficult because it includes the word "implementation" which stems from the Latin word *implere* which means to fill up (Carson, 2009). To fill up suggests that curriculum implementation is concerned with filling a gap in the knowledge and skills of teachers and learners. However, according to Rudhumbu (2018), implementation is the execution of something or the practical application of a technique, practice or desired purpose which involves a continuous adaptive and interactive process where variations in one facet of the implementation process lead to variations in other linked aspects (Beacco et al., 2010; Yang, 2013). Wiles and Bondi (2014) define curriculum implementation as "how teachers deliver instruction and assessment through the use of specified resources provided in a curriculum" (p. 17). Curriculum implementation involving a continuous adaptation process is relevant to the current research as teachers need to adapt to the 4IR.

The implementation of a curriculum being a process of change is concerned with possible forms of change which include changes to resources, practices, values and/or beliefs (attitudes), structures of the institution, the teachers and learners (DuFour, 2002; Fullan, 2002). Reiterating this theme of change, Carson (2009) describes curriculum implementation as commencing with the necessary communication which involves a move from the comfort of past practices of teaching to the oddness of new practices of teaching. This suggests that the curriculum implementation process occurs when there is a change from old practices to new practices.

Koskei (2015) affirms and adds to the discourse of curriculum implementation being a process by commenting that success is characterised by mandatory changes in practice by the teacher,

learner and the institution. Koskei's (2015) view is aligned with Fullan (2001) who earlier asserted that curriculum implementation is a process comprising of a) using new resources; b) engaging in new behaviours and practices and c) integrating new beliefs (attitudes). A common understanding of curriculum implementation is that it is a change process of interpreting theory into practice (Hall & Hord, 2011; Makaye, 2014, Ofoha, et al., 2009; Olofu, 2003; Sinnema, 2010).

The discussion outlined the problematic and often ignored concept of curriculum implementation as well as its process of change. Considering these leads one to ask: what processes can be used to enact curriculum implementation? Ornstein and Hunkins (2014) explain that the process of curriculum implementation consists of two phases, namely, the preoperational and operational phases. These phases encompass several key aspects of implementation which include human and material support, transformation strategies, communication pathways, professional development and instructional preparation (Beacco et al., 2010; Hamilton, 2014; Rusman, 2015).

2.5.1 Preoperational Phase

According to Nyagah (2001), the preoperational phase begins with orientating and mobilising all the stakeholders including teachers. This purpose is to foster positivity towards it and support for its implementation (Ornstein & Hunkins, 2014). According to Nyagah (2001), strategies that assist teachers in buying into the curriculum and its implementation include persuasion through seminars, workshops and professional development activities where positive elements of the curriculum are presented. The distribution of curriculum knowledge in these events empowers teachers with the necessary knowledge and skills to effectively implement the curriculum.

2.5.2 Operational Phase

The operational phase relates to the concrete implementation and management of a curriculum involving the distribution of a syllabus, learning and teaching support materials and facilities to all schools (Nyagah, 2001). These materials and facilities include textbooks, audio-visual materials, computers, classrooms, laboratories and workshops. The phase includes having plans for ongoing teacher development through refresher programmes for all curriculum implementers ensuring that they are capacitated with the current knowledge and skills. This ensures that teachers maintain levels of motivation and confidence. Both phases and their

respective aspects were considered when developing the framework to enhance the adoption of 4IR-based instructional strategies.

2.5.3 Forces Driving and Resisting Change

Discussing the implementation of a curriculum as a change process warrants the exploration of the forces which drive or resist it. According to Kritsonis (2005), the successful implementation and management of a curriculum requires a balancing act of these forces functioning in opposition to one another. Table 2.3 presents the forces that drive and resist change (Riley, 2015).

Table 2.3: Forces Driving and Resisting Change

Forces driving change	Forces resisting change
• Government interventions	• Fear of change
• Learner demands	• Threats to power
• Technological change	• Lack of knowledge
• Knowledge explosion	• School culture
• Pressure from supervisors	• Lack of resources
• Administration process	• Apathy
• Industry pressures	• Internal politics/climate
• New research practices	• Lack of time
• Social pressures	• Poor leadership
• Cost pressures	• Poor communication

The driving forces presented in Table 2.3 initiate and sustain change. For example, government interventions, learner demands, technological change and knowledge explosion can drive a school to consider better measures for successfully implementing a curriculum. Learners' demands and technological change are relevant to the current research as learner demands are related to the skills they need to develop in the 4IR and technological change is related to the 4IR technology. Resisting forces hinder the successful implementation of a curriculum and resonate with the current research as its problem (Section 1.2) is rooted in

factors that hinder the implementation of a curriculum. These resisting forces include fear of change, lack of knowledge and resources, school culture and poor leadership.

2.5.4 Change Management Model

Reflecting on the opposing forces (Section 2.5.3), consideration is given to how a curriculum can be implemented. Lewin (1947) proposed his Change Management Model for the implementation of change which is a three-step process used to implement a curriculum effectively due to its simplicity.

First, the unfreezing step assumes that human behaviour is supported by driving forces and aims to make individuals transform their current practices (Burnes, 2004, Kritsonis, 2005). For individuals to change their current practice they need to first acknowledge the need for the change. This occurs when they understand change and how it operates (Ornstein & Hunkins, 2014). This step overcomes an individual's resistance and norms by unlearning old practices.

Second, the moving step is necessary as unfreezing alone cannot be responsible for change. Even though it creates motivation to learn new practices, it cannot control the progression of the change (Burnes, 2004; Lewin, 1947). The moving step is the transition period involving a degree of confusion as individuals experiment and start to understand the new practices required by the change. Intrinsic to this step is the change in practices of individuals therefore denoting a period when old practices are challenged and new practices are attempted (Burnes, 2004).

Third, according to Kritsonis (2005), refreezing occurs once new practices have been implemented in the moving step. This step is marked by the new practices being established, a fresh mindset is crystalised and comfort levels start to return to prior levels (Sansone et al., 2003). According to Robbins (2003), this step is denoted by new practices, attitudes, knowledge and skills being infused into routines by reinforcement facilitated by formal and informal measures. Figure 2.9 is a representation of the three-step process for implementing change (Lewin, 1947).

Figure 2.9: The Change Management Model for the Implementation of Change
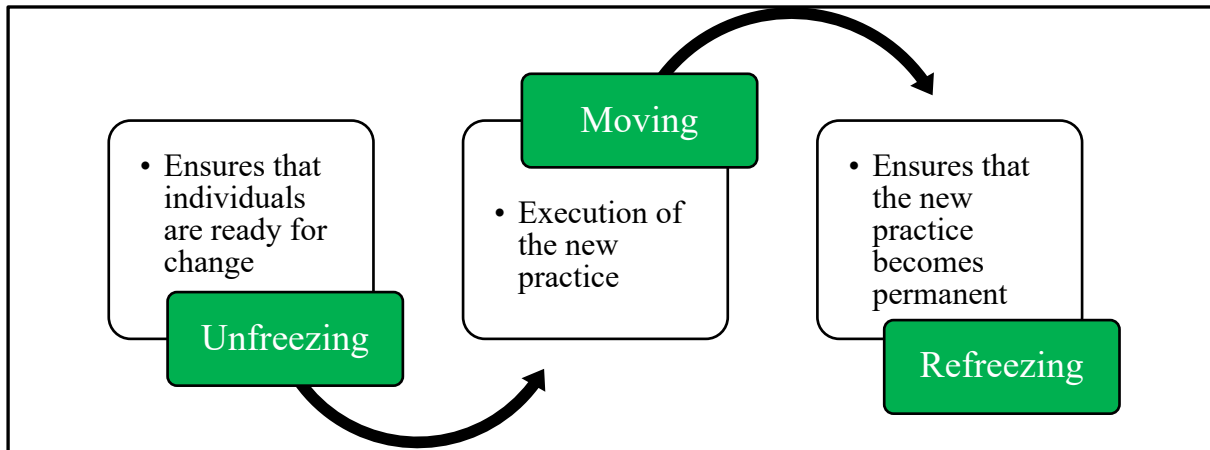
Source: (Adapted from Cummings & Worley, 2015)

2.5.5 Effective Implementation of a Curriculum

The effective implementation of a curriculum is explored in this Section as, during the review of literature, best practice was sought. The exploration in part informs the development of the framework to enhance teachers' adoption of 4IR-based instructional strategies. Hoover and Patton (2005) state that an effective curriculum implementation process uses various strategies to facilitate the development of knowledge, skills and ways of thinking of learners.

The Organisation for Economic Cooperation and Development (2009) views the effective implementation of a curriculum as the creation of a supportive classroom environment that provides learners with learning opportunities to develop creativity and innovativeness. Polikoff and Porter (2014) add that effective implementation of a curriculum is a cooperative process that aims to develop more than the knowledge of learners but also skills which include creativity, innovativeness, critical thinking, problem-solving and collaboration among individuals. This suggests that the process of effectively implementing a curriculum as a process involves practices that constantly support learner development concerned with their knowledge and skills.

Zhong (2006); Bennett (2007) and Davis (2011) include in their definitions educational praxis, shared decision-making and dynamic respectively. Zhong (2006) highlights the role of educational praxis explored by Paulo Freire who believed that individuals could change a condition first through reflection and second by action responding to the reflection. Bennet

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(2007) states that effective implementation is rooted in shared decision-making. Davis (2011), in referring to its being dynamic, asserts that constant redefining is essential as the need arises.

For teachers to effectively adopt 4IR-based instructional strategies an array of strategies must be employed as it is a dynamic process. These strategies should be supportive and cooperative where decision-making is shared. Individuals involved in the implementation of a curriculum need to reflect on new practices and then adjust as necessary.

2.6 CURRICULUM IMPLEMENTATION AND THE WAYS OF LEARNING

The discussion on the effective implementation of a curriculum (Section 2.5.5) established that opportunities for learners to develop creatively and innovatively need to be provided. Learners developing in this way involves learning being individualised as learners learn differently. This is in line with teaching and learning in the 4IR being learner-centred as it is personalised and self-paced (WEF, 2020). Teaching and learning that uses a learner-centred approach justifies a discussion around the different ways that learning occurs as a relationship exists between an individual's way of learning and teaching in terms of learner achievement (Olic & Adamov, 2018). The 4IR requires teachers to be mindful of the different ways of learning to decide, from available instructional strategies, which ones to adopt to facilitate a learner-centred approach.

The importance of a teacher considering the different ways of learning cannot be understated. According to Pritchard (2009), an individual performs better when they are instructed in techniques that are modified to their favoured learning style. Willis and Hodson (1999) state that an education model based on respect for learning styles includes the organisation of procedures according to the recognised learning styles, modification of the work schedule to the requirements of everyone, learning based on the pattern of the individual's work, genuine respect and acknowledgement of an individual's uniqueness and inclinations. Tubic (2003) adds to the discourse that awareness of individual learning styles significantly aids the teacher in choosing suitable approaches and instruction for the teaching process which supports the intrinsic motivation of individuals. This suggests that, by considering the different ways of learning when they select an instructional strategy to adopt, 4IR teachers will respect the uniqueness of individuals and contribute to motivating learners.

2.6.1 Ways of Learning

According to Mnguni (2019), learning theories explain how individuals acquire, retain and recall knowledge by incorporating a set of unique specific principles. Learning theories having different principles speak to the different ways individuals learn. Identifying the different ways of learning contributes to establishing teachers' understanding of 4IR-based instructional strategies in the current research. In a practical sense, if a teacher exhibits an understanding of the different ways of learning, then they understand a learner-centred approach which is intrinsic to 4IR instruction. The discussion starts with defining learning, moves on to the general principles of learning and then discusses several learning theories. The discussion of different learning theories includes theories which incorporate technology as 4IR-based instructional strategies encompass technology.

2.6.1.1 Learning

According to Mnguni (2019), learning is "a continual process of acquiring attitudes, knowledge and skills through connections between sources of information and the formation of useful patterns" (p. 38). This definition incorporates more aspects than that of Pritchard (2009) who previously defined learning as a process of acquiring knowledge through experience resulting in changed behaviour. The additional aspects incorporated by Mnguni (2019) include learning being continuous and involving more than the mere attainment of knowledge that is facilitated through making links between information. Pritchard (2009) did, however, categorise learning as unplanned or planned. Unplanned learning regularly goes unnoticed as it is perceived as something which occurs naturally and is referred to as the 'normal' form of learning. Evidence of unplanned learning going unnoticed is when a child performs a task that they could not previously perform. In this form of learning, specific skills and understandings are established by parents spending time assisting the child.

In contrast, planned learning occurs in more formal settings and enhances the 'normal' form of learning. These formal settings are inherent in educational systems, for example, playgroups, nurseries and schools. Here children are "taught and initiated into accepting the knowledge and skills base that is considered to be essential if they are to grow into citizens of our society who can function and contribute effectively" (Pritchard, 2009, p. ix).

The discussion recognised that learning involves experiences and is a continuous process where an individual acquires several competencies. It also established that learning can be planned or

unplanned. Defining learning leads to recognising the principles of learning. This is important as one needs to be aware of the general conditions that facilitate learning. Table 2.4 provides an overview of the ten general principles of learning (Potter, 1991):

Table 2.4: The Ten General Principles of Learning

Principle	Description
Connectedness	Learning is facilitated by the interaction between the mind, environment, context, self, negotiation and practice.
A compelling situation	Learning involves stimulating and applying the brain's ability to conceptualise, consider and deliberate on experiences.
An active search for meaning	Learning is an active quest for meaning by creating knowledge that is shaped by experiences.
Development and holism	Learning involves the complete person and is a progressive, and collective process.
Social interaction	Learning is enhanced by cooperation and sharing as individuals are inherently social beings.
Learning climate	Learning is influenced by the educational climate in which it occurs.
Feedback and use	Learning involves frequent feedback and the opportunity to use what has been learnt.
Incidental learning	Learning occurs casually and incidentally through casual interactions with peers, social and community involvements and unintentional situations.
Groundedness	Learning is rooted in specific contexts and individual experiences, demanding an effort to apply knowledge and skills to comparable and other circumstances.
Self-monitoring	Learning encompasses the skill to monitor own learning.

Source: (Adapted from Potter, 1991)

Summarising the general principles of learning in Table 2.4, leads one to assert that learning is an experience involving several complementary facets. A 4IR teacher needs to consider them to select the appropriate instructional strategy that incorporates the general principles of learning. What follows is a description of learning theories considered when seeking to

accommodate an individual's different way of learning. Being aware of different learning theories caters for individual learners in the development of the skills required in the 4IR.

2.6.1.2 Behaviourism

Behaviourism views learning as an observable transformation of behaviour or the acquisition of new behaviour (Orlich et al., 2010; Pritchard, 2009). Initiated by Skinner, behaviourism involves the concept of operant conditioning which is the reinforcement of behaviour by rewarding it. According to Pritchard (2009), reinforcement can be positive or negative and is an action or gesture which strengthens a specific behaviour. This strengthening of a specific behaviour results in the likelihood that it will occur again. Positive reinforcers in the classroom are rewards for desirable behaviour which include but are not limited to praising the learner. The learner secures approval or attention. In contrast, negative reinforcers decrease the likelihood that a behaviour will occur again. When an undesirable behaviour occurs, it is matched with an unpleasant action or comment; although effective, it is viewed as punishment and can harm the learner. There may be negative emotional responses experienced by the learner which include anger and frustration.

Mnguni (2019) in analysing behaviourism notes that it is initiated by a stimulus which a learner responds to in the form of behaviour which is assigned a reinforcement determined by whether the behaviour is desirable or undesirable. It is envisaged that the new behaviour can be repeated and become instinctive. The change of behaviour to the desired one represents learning. In critiquing behaviourism, Pritchard (2009) states that it is not recommended to rely exclusively on behaviourism for teaching and learning in the classroom as it gives little importance to the concepts of formation of understanding.

2.6.1.3 Cognitivism

According to Orlich et al. (2010), cognitivism aims first to develop a learner's thinking skills from a basic level to a more skilled level over time by teaching them how to learn new information efficiently. Second, it provides experiences where they structure their learning themselves. This suggests that cognitivism posits that learners are actively engaged in their learning. The cognitivism learning theory is grounded in the thought process which produces a behaviour (Mnguni, 2019; Orlich et al., 2010; Pritchard, 2009). In contrast to behaviourism, where a learner responds to a stimulus, cognitivism is when the learner processes received

information. The changed behaviour reflects what is taking place in the learner's mind in terms of their processing of information.

2.6.1.4 Constructivism

Research into the learning theory adopted by teachers in teaching scientific knowledge advocates the adoption of the constructivist approach for the teaching and learning of scientific concepts (Baxter, 1991). The emphasis is on the learner, where the interaction between the teacher and learner is not perceived as one which involves the teacher pouring knowledge into a passive learner waiting like an empty vessel to be filled. Rather the learner is encouraged to actively participate in their own learning experience. Knowledge is organised and intertwined into the learners' cognitive structures. It involves the "active participation of learners in abstracting relevant features of new knowledge and either assimilating these features into their cognitive structures or reorganising their structures to accommodate these features" (Zelik et al., 1997, p. 998). Wheatley (1995) describes it as the individual making sense of their experiences. Baxter (1991) suggests that a benefit of the constructivist approach is enhancing teaching practice and believes that part of it is the designing of tests that challenge the learner's original notions. Ozer (2004) writes that within a constructivist classroom, there is a variety of activities to meet learners' diverse needs, increasing their readiness to learn through the discovery of new ideas in the construction of their knowledge.

Constructivism and social constructivism as theories both call for the construction of knowledge and are similar. According to Ozer (2004), they differ in that social constructivism places a greater emphasis on the learning experience being a collaborative activity incorporating social interaction that values cultural backgrounds. A social constructivist classroom calls for school learning to take place simultaneously with real-world learning.

Adding to the discussion on constructivism as a learning theory is an inquiry-based approach to learning developed by John Dewey falling within the ambit of constructivism. According to Andrini (2016), inquiry learning is an active course in which the construction of new understandings is grounded on prior experiences. Horan (2020), succinctly states that the inquiry-based approach:

> places learners at the centre of meaningful, real-world learning which is conceptually driven. It is dynamic and requires teachers to foster a habit of key inquiry skills for learners such as: questioning, observing, investigating, reflecting

and taking action. It engages learners through collaborative and transdisciplinary learning. (p. 19)

These skills link well with the five phases of the 5E learning cycle model for inquiry learning, namely, engagement, exploration, explanation, elaboration and evaluation (Bybee et al., 2006).

2.6.1.5 Connectivism

According to Siemens (2004), learning is a process of connecting specific links or knowledge resources. This understanding of learning coupled with the internet's influence on knowledge gave rise to the learning theory of connectivism which is rooted in distributed learning in a digital society. Bates (2015) views the theory of connectivism as the first theory to re-evaluate the influence on learning due to the internet and the upsurge of innovative communication technologies. Knowledge is dynamic and cannot be created by a single individual nor can it be controlled by an organisation; rather, there needs to be an acknowledgement of this dynamic knowledge to gain meaning from it (Bates, 2015).

Downes (2012) a proponent of connectivism states that "knowledge is distributed across a network of connections, into its nodes and therefore, learning consists of the ability to construct and transverse those nodes connected into networks" (p. 9). According to Herlo (2017), a node can be an individual, a group of individuals, a computer or a community that is part of a network where there is an interconnectedness between them. This interconnectedness is the change in the information in one node influencing the information in another node. Herlo (2017) adds that connection to the networks of nodes facilitates the sharing of information that can be transformed by understanding.

The connective understanding of learning was explained and modelled with the development of the original massive open online course (MOOC). The development of the MOOC applied the connectivism learning theory to assist individuals in understanding the transformative influence technology has on teaching and learning. Downes (2014) described the MOOC as follows: (a) it is a course which engages individuals in the learning practice through collaborating with others on a particular network; (b) it is open due to it being free and accessible to individuals where work is shared; (c) it is participatory/interactive as it includes individuals performing a variety of actions with their brains; (d) a distribution element can be identified in it being distributed by applications such as YouTube and Google; and (e) it affords

individuals the opportunity to work independently in their own space, choosing what they want to do and how they want to participate, and deciding if they have achieved their outcomes.

According to Herlo (2017), the chief role of the teacher is to present individuals with the environment and the primary learning context for being together. After this, the teacher takes on the role of an advisor to individuals to build their learning environments that allow for the connection to learning achievement networks. There has been criticism levelled at the connectivism learning theory. However, according to Bates (2015), such criticism will be overcome through improved practice and the development of new assessment tools.

2.6.1.6 Online collaborative learning

Harasim (2017) proposed the online collaborative learning (OCL) theory of acquiring knowledge which focuses on collaborative learning and the use of the internet in the construction of knowledge. The OCL includes three stages of knowledge construction through group discussion. According to Harasim (2017), Stage 1 involves producing ideas where different views are gathered through brainstorming. Stage 2 is the organisation of the ideas produced in stage one where ideas are classified through discussion. Lastly, Stage 3 is the consolidation of intellect where consensus occurs through a task. The three stages of OCL suggest that it is collaborative as individuals work together to solve problems.

An analogy of a pod of dolphin calves who have no real hunting experience can be applied to illustrate the OCL. Each calf represents an individual with different ideas. When hunting, each calf has a different view of how the hunt should take place. This represents Stage 1 of OCL which is concerned with brainstorming. Communicating via clicks, whistles, bumping into one another, leaping out of the water as well as slapping their tales and flippers on the water represents Stage 2 of the OCL as their ideas are being organised. The calves then decide on the appropriate way to complete the hunt successfully. This represents Stage 3 of the OCL and results in a collaborative outcome in solving the problem of obtaining food.

2.6.1.7 Engagement theory

The engagement theory forms part of a new wave of theories for teaching and learning in the information age where central to it is the positive influence technology can have on human relations and evolution (Magout, 2020; Reaves, 2019). The theory is associated with the concepts of constructivism, situated learning and experimental learning as these concentrate on

collaborative endeavours and project-focused activities that produce innovative, insightful, and reliable learning (Kearsley & Shneiderman, 1998; Magout, 2020).

According to Dickey (2005), important to engaged learning are social interactions and collaborations allowing learners to participate in a community of practice. The theory calls for the engagement of students to be at the centre of learning where maximum interaction with other students in meaningful activities is encouraged (Allen & Lester, 2012; Clarà & Barberà, 2013). Schneiderman (1994) states that this theory requires students to engage in functional cognitive activities which include formulating, problem-solving, analysing, decision-making and evaluation. Additionally, engagement produces intrinsic enthusiasm in students to learn due to the quality of the environment created and activities (Schneiderman, 1994). Technology can aid in enabling all aspects of engagement in ways not easily accomplished without it (Magout, 2020). The use of technological tools such as online discussions, conferencing, emails, chat and video conferencing creates a conducive environment for engagement among all contributors.

2.7 FOURTH INDUSTRIAL REVOLUTION INSTRUCTION

Instruction is an important component of teaching and learning. This Section discusses instruction, applying its components to determine instruction in the 4IR with the instructional strategies which create a classroom environment where learners experience quality learning (Akdeniz, 2016). This suggests that instructional strategies are an aspect of a teacher's practice relevant to instruction to secure the acquisition of the needs of learners in the 4IR. Determining instruction in the 4IR identifies the instructional strategies for it and is used as an instrument to evaluate the degree of change if any required by teachers in the 4IR. This contributes to determining their readiness and the development of a framework to enhance the readiness of in-service Life Sciences teachers to adopt 4IR-based instructional strategies.

According to Dick and Carey (1996), instruction deals with teaching and learning activities which is an organised action where every element is crucial for successful learning to take place. These elements include teachers, learners, resources and the learning environment. Effective instruction enables learners to acquire specific skills, knowledge and attitudes.

Various instruction models have been proposed to facilitate teaching and learning; for example, the Dick and Carey model and the Smith and Ragan model. Intrinsic to these models are the aspects upon which they hinge. In terms of these aspects, the first is the identification of the

needs of potential learners. Second, is the formulation of a strategy to address the identified needs of the potential learners. This strategy includes the selection of the appropriate instructional strategies. Third, once the instructional strategy is selected and adopted, it is evaluated to revise or adjust it for future use. Since instruction involves considering several elements for context and attention given to its various aspects, this is in line with Glickman (1991) who states that:

> Effective teaching is not a set of generic practices, but instead is a set of context-driven decisions about teaching. Effective teachers do not use the same set of practices for every lesson. Instead, what effective teachers do is constantly reflect about their work, observe whether students are learning or not, and then adjust their practices accordingly (p. 6).

Effective teaching is planning and designing instruction from theories that have proven successful in the past (Molenda et al., 2003; Smith & Ragan, 1999). This is pertinent to this discussion as past works on instruction are used to underscore the determination of instruction in the 4IR. However, due to the nature of the 4IR recent and applicable works are explored to ensure relevance.

There are five types of instructional strategies: direct instruction, indirect instruction, interactive instruction, experiential learning and independent study (Nuraidah et al., 2021). These instructional strategies determine the method adopted by a teacher to attain the learning outcomes and therefore the needs of the learners. The five types of instructional strategies are not viewed in isolation as they interact and can be combined within a learning experience. For example, a teacher might adopt direct instruction in the form of the lecture method to provide information and later adopt indirect instruction through an interpretive method when asking learners questions to determine the importance of the information presented. Figure 2.10 illustrates the five types of instructional strategies.

Figure 2.10: The Types of Instructional Strategies
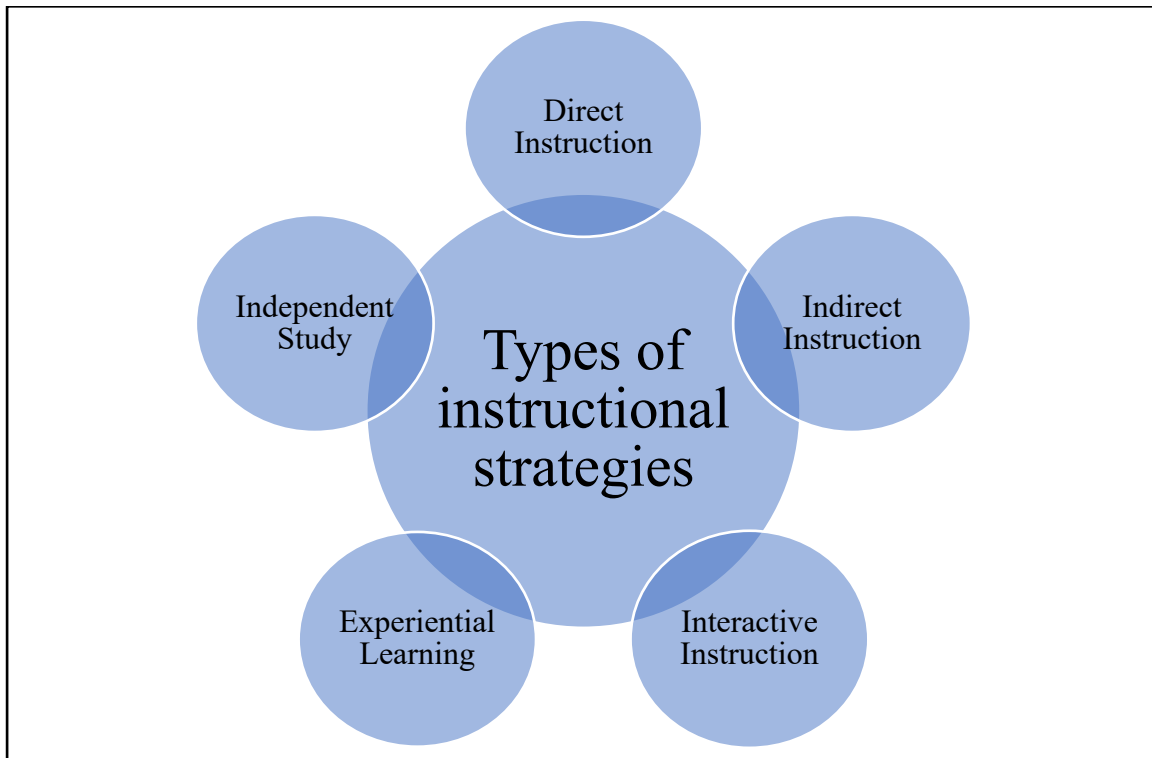
Source: (Adapted from Nuraidah et al., 2021)

Figure 2.10 represents the five types of instructional strategies which are linked. This linking represents how these instructional strategies interact with one another and how they can be amalgamated within a teacher's teaching practice to develop the skills required in the 4IR. On this note of amalgamating instructional strategies and linking it to the discussion on the implementation of a curriculum which considers the different ways of learning (Section 2.6), is the recognition of the concept of differentiated instruction.

2.7.1 Differentiated Instruction

Also known as pedagogical differentiation, it "seeks to maximise each student's growth by recognising that students have different ways of learning, different interests, and different ways of responding to instruction" (Ravitch, 2007, p. 75). According to Eikeland and Ohna (2022), differentiated instruction is linked to inclusion and personalised learning. Tomlinson (2014), a proponent of differentiated instruction, explains that it is the engagement of learners facilitated through "different approaches to learning, by appealing to a range of interests, and by using varied rates of instruction along with varied degrees of complexity and differing support systems" (p. 3-4). It is a proactive and learner-centred approach that provides different ways of

acquiring content, processing ideas, and developing products (Tomlinson, 2017). Figure 2.11 represents the components that a teacher needs to consider in differentiated instruction.

Figure 2.11: Components of Differentiated Instruction
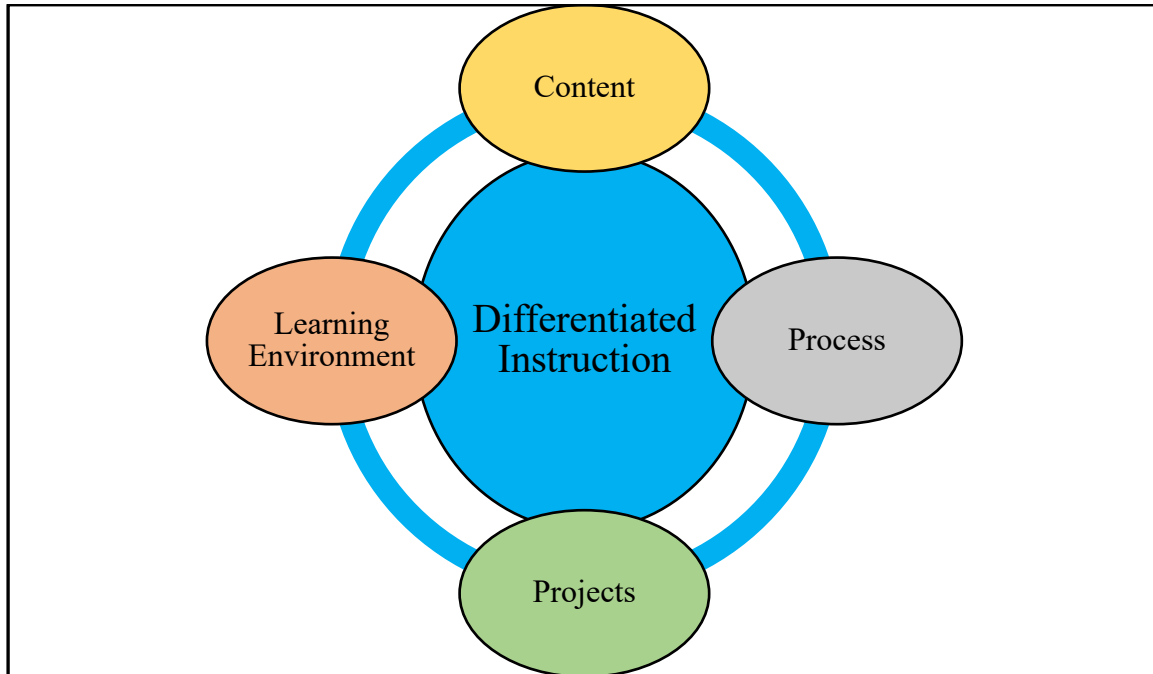
Source: (Adapted from Tomlinson, 2017)

According to Tomlinson (2017), the content in Figure 2.11 refers to what a teacher includes in what a learner needs to learn and the resources required. Processes are the activities that facilitate the learner making sense of what they learn. Projects are the ways the learners illustrate what they know, and the learning environment relates to how the classroom feels and how the learners work together. All these components are considered to appeal to different learners to create an environment that promotes learning. This is in line with learning in the 4IR being personalised and self-paced, a learner-centred approach to teaching and learning (WEF, 2020). The 4IR requires teachers to be mindful of the array of instructional strategies and the ones to adopt to facilitate a learner-centred approach.

2.7.2 Direct Instruction

Direct instruction, also known as active teaching, explicit instruction or whole-class teaching is one of the most used strategies and is highly teacher-centred (Akdeniz, 2016; Nuraidah et al., 2021). Its effectiveness is based on providing information and the development of step-by-step skills. According to Muijs and Reynolds (2018), direct instruction involves the teacher

actively engaging in bringing the content to learners by teaching directly and is effective when teaching rules, procedures and basic skills. It has limitations when developing thinking skills and is less effective when the outcomes are complex. It is often used to initiate other instructional strategies which actively involve learners' knowledge construction. The aspect of this strategy of initiating others is in line with the interrelationship between the five types of instructional strategies. Examples of direct instruction methods include demonstrations, lectures, questioning, practice and drill and explicit teaching.

2.7.3 Indirect Instruction

Indirect instruction is rooted in student-centredness as it involves a high degree of learner involvement which contrasts with direct instruction. The high degree of involvement is evident in learners forming hypotheses, investigating and observing. Even though the two strategies are different, they can complement each other. Akdeniz (2016) adds that indirect instruction uses the learners' curiosity and interest when they are encouraged to solve problems. The learners' curiosity and interest allow for flexibility and creativity as they are allowed to explore different possible solutions, reducing anxiety associated with providing an incorrect answer. In exploring various possible solutions, indirect instruction nurtures the development of interpersonal skills and competence. Examples of indirect instruction methods include reflective discussion, case studies, guided inquiry and problem-solving.

The issue of the fitness of indirect instruction can be addressed in response to the question of when indirect instruction methods are appropriate. The Saskatchewan Ministry of Education (SMOE) (1991) identified these as when:

> thinking outcomes are desired; attitudes, values or interpersonal outcomes are desired; the process is as important as the product; students need to investigate or discover something to benefit from later instruction; there is more than one appropriate answer; the focus is personalised understanding and long term retention of concepts or generalisations; ego involvement and intrinsic motivation are desirable; decisions need to be made or problems need to be solved; and, lifelong learning capability is desired. (p. 4-5)

There are disadvantages to indirect instruction which include that it is time-consuming; teachers give up a certain degree of control; outcomes can be unpredictable; they are,

unsuitable for developing and promoting step-by-step skill achievement; and it is not recommended where the outcome is content to recall through memorisation.

2.7.4 Interactive Instruction

According to Nuraidah et al. (2021), interactive instruction is highly dependent on discussion and the sharing of ideas among learners with the teacher. This suggests that through such discussions their social skills will be developed. Examples of interactive instruction methods include whole-class or small group discussions, debates, brainstorming, role-playing, cooperative learning, jigsaw, projects and learner pairs working on assignments.

2.7.5 Experiential Learning

Experiential learning like indirect and interactive instruction is learner-centred. It is activity-based which involves a personal reflection on the activity (experience) leading to the application of what is learnt to other settings. McPherson-Geyser et al. (2020) combined the experiential learning models of Dewey (2001) and Kolb (1984) to propose a model for it which is represented in Figure 2.12.

Figure 2.12: The Representation of an Experiential Learning Model
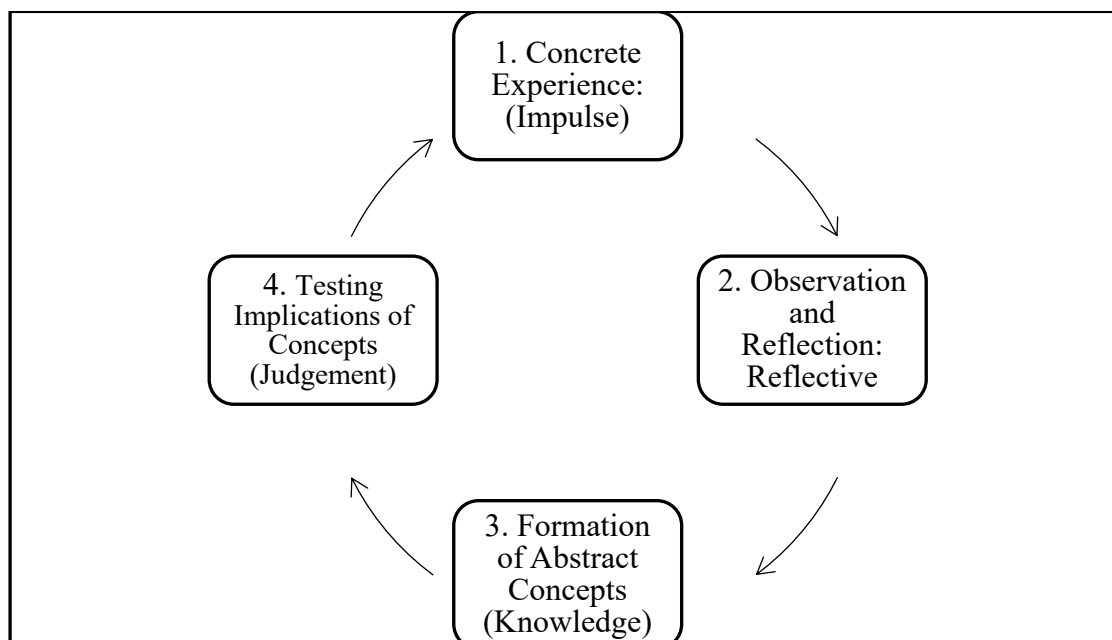
Source: (Adapted from McPherson-Geyser et al., 2020)

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According to McPherson-Geyser et al. (2020), concrete experiences serve as stimuli when a learner experiences a new situation that they do not understand. Observation and reflection are the use of the observations from the concrete experience. The learner activates their prior knowledge to base the concrete experience on past circumstances. The aspect of the formation of abstract concepts involves the learner focusing on the abstract concept about discoveries and plausible theories. In the conceptualisation of abstract concepts, relationships between known theories are realised. The fourth aspect of testing the implications of concepts involves the learner in active experimentation applying what has been taught by making connections to the real world. Examples of experiential learning methods include experiments, role-playing, field trips and games. This suggests that experiential learning can take place in and out of the classroom.

2.7.6 Independent Study

In independent study, importance is placed on developing a learner's ability to plan and pace their learning (Akdeniz, 2016), suggesting that it is flexible. Independent study can be used in tandem with other instructional strategies where the teacher supervises and guides learners through the learning experience. To assume this role, factors such as learner maturity and self-reliance need to be considered by the teacher when planning to use independent study as an instructional strategy. Independent study can also include learning with another individual or being part of a small group. The purpose of independent study is to develop learner initiative, self-reliance and self-improvement. Examples of independent study methods include computer-assisted instruction, essays, reports, learning logs and research projects.

Learners being responsible for the planning and pace of learning aligns independent study with self-directed learning (SDL). According to Boyer et al. (2014), learners in SDL establish their learning outcomes, choose the resources to achieve these outcomes, select the appropriate strategy and reflect on the result of the learning process. The learners assume responsibility for their learning process (Bosch, 2017). This suggests that SDL is a learner-centred approach to learning. Important to SDL is that "individuals will vary in their readiness for self-direction thereby requiring varying degrees of assistance by facilitators, especially as SDL skills are developing" (Brockett & Hiemstra, 1991, p. 10). This suggests that a differentiated methodology with sufficient support might be necessary. Considering this support, SDL is described as a social endeavour (Johnson & Johnson, 2009). In terms of supporting learners in

SDL, Bosch et al. (2019) recognise that teachers still have a role in facilitating SDL through which learners attain higher levels of directedness.

2.7.7 Suggesting 4IR-Based Instructional Strategies

Skills are required to be developed by learners for them to succeed in the 4IR (Section 2.2.4). The P21CL (2019) identified these skills namely life and career skills, learning and innovation skills, information, media, and technology skills which encompass skills identified by other contributors to the topic (Gray, 2016; WEF, 2020). From these skills, one is positioned to establish 4IR-based instructional strategies to develop them which include direct instruction, indirect instruction, interactive instruction, experiential learning and independent study. Throughout the discussion, reference is made to skills to substantiate the determination of the appropriate instructional strategies to be adopted by in-service Life Sciences teachers in or for the 4IR.

As explained in Sections 2.7 and 2.7.2, although direct instruction is teacher-centred which is counter to learning in the 4IR being learner-centred, it can be used to assist other instructional strategies in the development of the skills required in or for the 4IR. A teacher can use direct instruction as an instructional strategy to introduce another instructional strategy that will develop the required 4IR skills. This suggests that direct instruction can be an aspect of the 4IR-based instructional strategies adopted by in-service Life Sciences teachers.

One of the skills included in learning and innovation skills is creativity and innovation. An instructional strategy which could develop this skill is indirect instruction as it is learner-centred involving learner involvement in line with a learning experience in the 4IR (WEF, 2020). Indirect instruction involves guided inquiry and problem-solving which is related to the skill of critical thinking where the learners' curiosity and interest are used to solve problems. Learners using their curiosity and interests to solve problems is in line with the development of the skills of flexibility and creativity to be developed in the 4IR (Akdeniz, 2016). By being flexible and creative learners may interact with others developing skills related to career and life skills which include people management, leadership and responsibility, coordination with others, interpersonal emotional intelligence, negotiating and social and cross-cultural skills.

The development of communication and collaboration skills can be developed through interactive instruction as it involves discussion and the sharing of ideas among learners as well as with the teacher. Through discussions, a learner's social skills will be developed which are

aligned with the skills required by individuals in or for the 4IR (Gray, 2016; P21CL, 2019; WEF, 2020). Other skills developed depending on the nature of the activity include people management, negotiation and flexibility. This suggests that interactive instruction is an applicable instructional strategy to be adopted for the 4IR.

Experiential learning, being learner-centred, suggests its applicability to 4IR-based instructional strategies as learning experiences in the 4IR involve catering to the diverse individual needs of each learner (WEF, 2020). In summary, experiential learning involves a learning experience that includes a learner participating in an activity based on when it occurs and its phases (SMOE, 1991) where inferences are made through observation and reflection of the activity. These inferences are then applied. This suggests that experiential learning is closely aligned with the scientific method used in Life Sciences. Demonstrating experiential learning as a 4IR-based instructional strategy is that an activity could require learners to critically think to solve a problem identified in the activity. The critical thinking skills would be developed by learners reflecting on the problem. In solving the problem, learners are encouraged to be creative and innovative therefore developing the skill of flexibility in their approach to problem-solving. The skill of flexibility will be developed through the suggestion that experiential instruction can take place in and outside of the classroom requiring learners to be flexible to adjust to the different settings. The skills of communication and collaboration can be developed by their participation in their activity and the sharing of ideas to solve the problem.

Independent study, as the term suggests and in line with Akdeniz (2016), is focused on the learner's ability to self-direct in terms of the planning and pace of learning. This instructional strategy will therefore develop skills such as self-direction, productivity, accountability and flexibility.

This discussion suggested several instructional strategies applicable to the 4IR based on the skills that they develop. The relevance of this is informed by the diversity of learners having different learning needs. Their differing learning needs would be met by teachers adopting the instructional strategies identified and importantly their combination for learning experiences. According to the SMOE (1991), instructional strategies should not be perceived as separate entities as, where necessary, there is an interaction between them. The use of a combination of the different instructional strategies enables learning to be dynamic or flexible. This flexibility

allows learning experiences to be stimulating and different for learners to develop their curiosity, interest and motivation toward the topic of study.

Recognising the adoption of a combination of applicable 4IR-based instructional strategies points to a discussion concerned with an aspect of 4IR learning. According to the P21CL (2019), schools must weave in interdisciplinary themes in key subjects. The concept of interdisciplinarity can be extended to the adoption of the use of a combination of instructional strategies. A combination of instructional strategies that is consistent with differentiated instruction (Section 2.7.1). A large percentage of teachers in South Africa are not competent to facilitate learning in the 4IR as they are using traditional methods in their teaching practice (Moloi & Mhlanga, 2021). Teachers may not have an understanding of what constitutes interdisciplinary relations between entities manifesting in them not being able to identify the value of a particular instructional strategy to be used in combination with others. This could be detrimental to achieving a holistic learning experience for a diverse group of learners who have different learning needs.

2.8 SUMMARY OF LITERATURE COVERAGE

This chapter covered various aspects related to the topic of the current research. Figure 2.13 represents the distribution of literature discussed concerning the major themes of this chapter.

Figure 2.13: Distribution of Literature Discussed
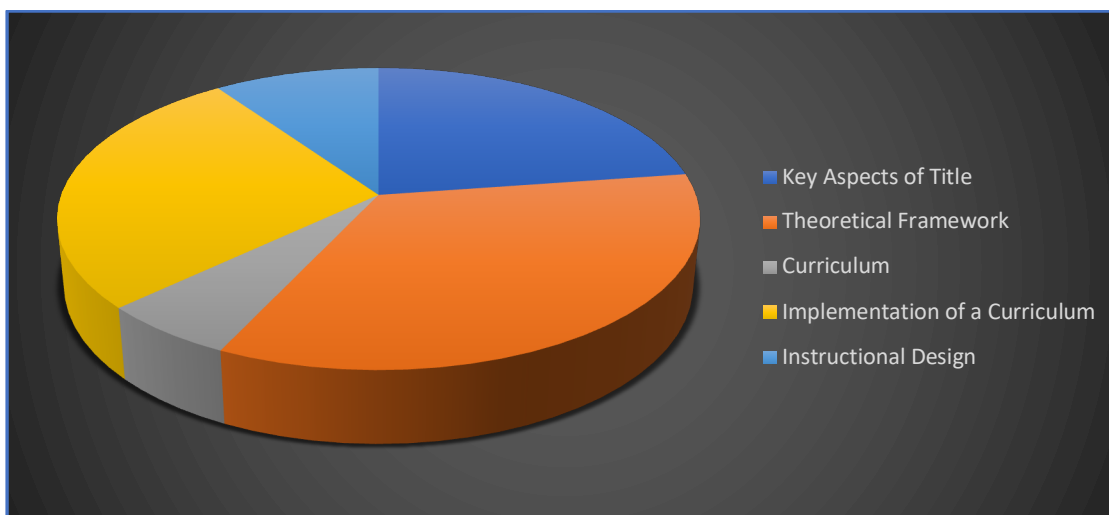
Figure 2.13 represents the distribution of literature covered in this chapter. Key aspects of the title included literature concerned with the 4IR, the concept of change, the role of education in

society, educational change and the needs of the 4IR contributing to the applicable instructional strategies. The identification and justification of the theoretical framework included discussions on the RRCM (Holt, 2007), the influence of attitudes and understandings on the readiness for change and the UTAUT (Venkatesh et al., 2003), and contributed the most to this chapter. The concept of curriculum was then discussed which included defining it, identifying the ideological nature of a curriculum and presenting it diagrammatically. This led to a discussion concerned with the implementation of a curriculum where effective implementation involves a consideration of the ways of learning. Finally, instructional design was discussed which explored instruction in the 4IR and included types of instructional strategies.

2.9 CONCLUSION

Through the review of the literature identified, this chapter discussed and justified the theory that underpins the current research guided by the research questions. Relevant themes focused on theory related to the 4IR, the readiness for change and curriculum which includes teaching and learning and instructional design. These themes were contextualised to the current research by applying them.

The next chapter presents and explains the research methodology employed in the current research to respond to the research questions. These responses, which were used to develop a framework for enhancing the readiness of in-service Life Sciences to adopt 4IR-based instructional strategies.

CHAPTER 3: PLOTTING THE ROUTE OF THE JOURNEY

"To solve any problem, here are three questions to ask yourself: first, what could I do? second, what could I read? and third, who could I ask?"

Jim Rohn

3.1 INTRODUCTION

The previous chapter identified and explored the theory that underpins the current research. This chapter presents and discusses the research methodology employed to answer the research questions and achieve its aims. This research methodology includes the research paradigm, research approach, research design and research methods. The chapter continues with the exploration of the measures which secured the trustworthiness. In conclusion, there is a presentation of the measures employed to secure the ethical aspects involved in the current research. Throughout the chapter and related to each Section is the justification for selecting the relevant component.

3.2 RESEARCH METHODOLOGY

Humans have an innate desire to understand the environment they inhabit and the underlying reasons that define their existence (Cohen et al., 2007). The pursuit of this comprehension is facilitated by research methodologies which relate to the implementation of detailed designs and methods. Jackson et al. (2007) state that methodologies reveal how inquiries progress by identifying what problems are understandable for investigation; how to structure enquiries making the investigation possible; how to generate specific data; and how to make inferences linking the problem, data generated and analysis and conclusions.

Henning et al. (2004) claim that the methodology is a collaborative view to obtain data and findings that convey the research questions that achieve the research aims. This suggests that methodology consists of several components selected and implemented that agree with the rationale of the research. The current research, concerned with the phenomenon of teacher readiness to adopt 4IR-based instructional strategies determined the components of the research methodology.

Cohen et al. (2000) highlighted the importance of the research methodology with data collection instruments as generating the appropriate data to address the research questions of

a study. According to Jackson et al. (2007), research methodology expresses how the research progresses, highlighting the questions set out for investigation, how to structure the research so that discovery is possible, how to produce precise methods of data generation, and how to reason between questions, data generation, analysis and conclusions. Henning et al. (2004) further explain that the methodology presents an overview to supply data and findings that answer the research questions that achieve the aims of the research. This suggests that the research methodology draws from the selection and adoption of appropriate methods aligned to the aim of the study. Therefore, merging the data generation and interpretation activities with the research questions ensures that all research features are included. Hence, data generation is a vital component of research because its absence will not allow the researcher to base his or her claims on evidence.

The selection of the components of the research methodology of the current research secures a deep understanding of the phenomenon. Figure 3.1 summarises the key components of the research methodology used to respond to the research questions of the current research.

Figure 3.1: The Key Components of the Research Methodology
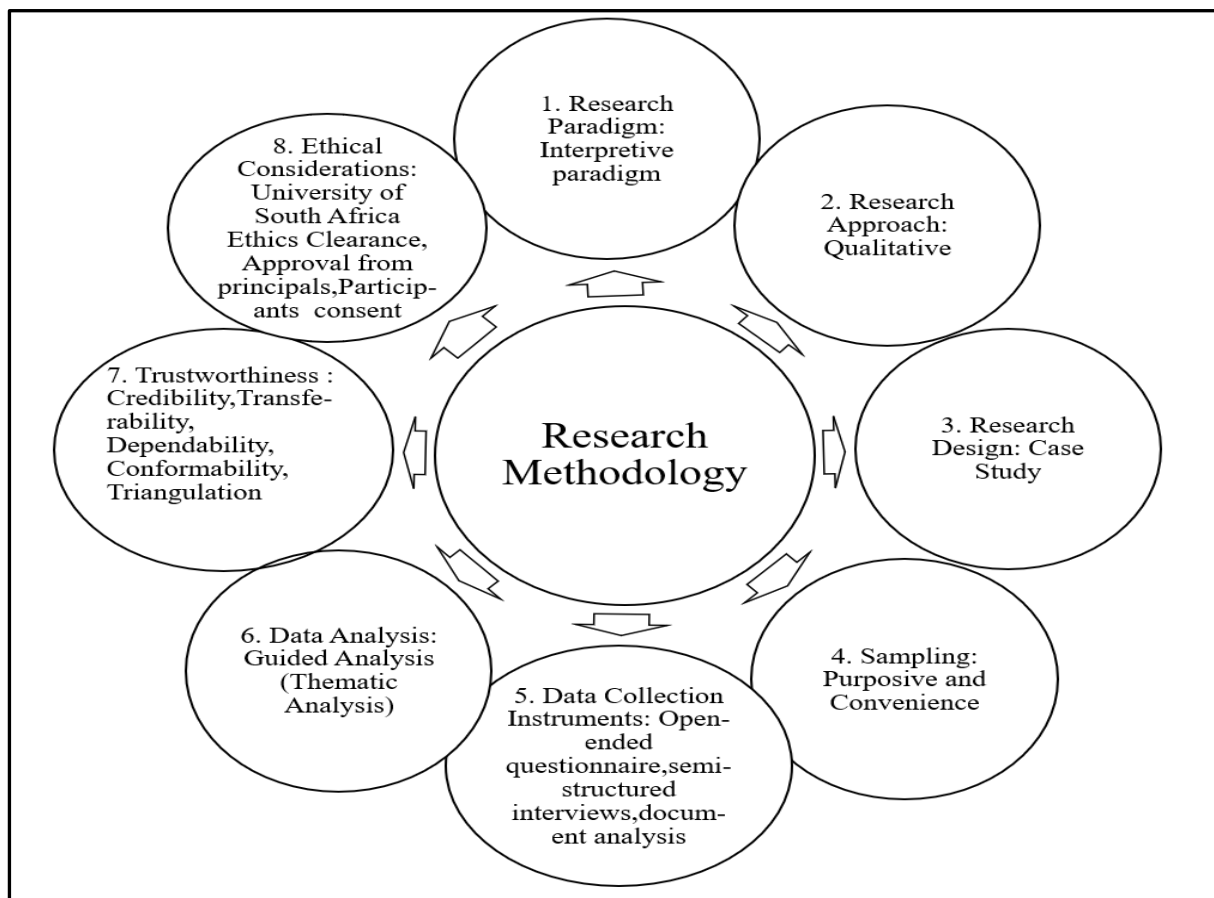
Section 3.3 discusses the research paradigm of the current research which informs the other components of the research methodology.

3.3 RESEARCH PARADIGM

Numerous scholars have defined a research paradigm. According to Guba and Lincoln (1994), a paradigm is a collection of fundamental beliefs that represent the worldview of an individual explaining the nature of the world. Where the individual considers their relationships to that world and its components. Originating from the Greek word 'paradeigma' which means pattern, the concept of a paradigm was first used by Kuhn (1962) to suggest a conceptual framework used by scientists to explain the study of problems to find solutions. Kuhn (1962) writes that a research paradigm is a set of general beliefs held by researchers on the methods by which problems or phenomena are to be investigated. These beliefs are used to acquire the necessary knowledge to investigate the phenomenon.

Terre Blanche et al. (2006) view paradigms as "acting as perspectives that provide a rationale for the research and commit the researcher to particular methods of data generation observation and interpretation" (p. 40). Christiansen et al. (2010) add that a paradigm supplies a researcher with the questions to be posed, leading to what observations and investigations can occur, and how data will be generated and analysed. These definitions suggest that a paradigm is a method of viewing the world outlining the way a researcher attempts to respond to research questions. In assigning value to a paradigm, Miskon et al. (2015) state that thorough research relies on the formation of a research paradigm that guides and directs the analysis and interpretation of the data. This suggests that effective research is achieved by identifying and implementing the appropriate paradigm for specific research.

In essence, research paradigms represent the multiple views, opinions and conventions regarding how the world is understood. These are different and relative to a particular context that forms reality for individuals. Hence, different research paradigms exist which represent the different views and beliefs about reality. Figure 3.2 summarises the aspects intrinsic to paradigms in general. Essentially, a paradigm provides a lens for viewing a phenomenon and requires certain procedures relevant to it to conduct the research which will enable the research questions to be addressed.

Figure 3.2: Aspects Intrinsic to Research Paradigms
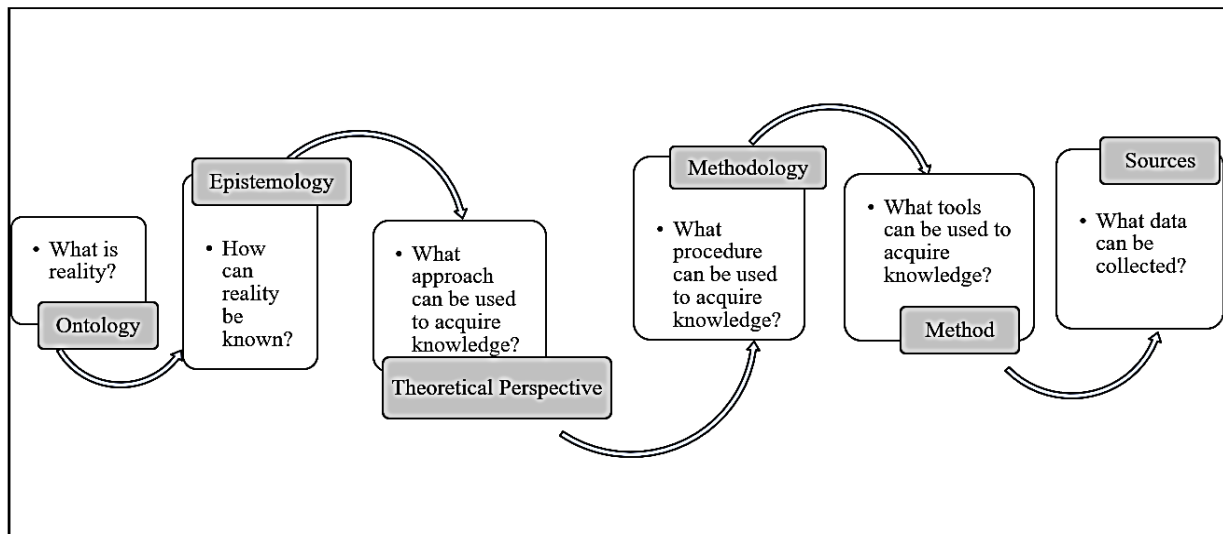
The aspects intrinsic to paradigms depicted in Figure 3.2 are informed by a certain question. A particular paradigm has a specific response to each aspect's question. The following discussion establishes the paradigm selected to explore the phenomenon of the current research and explores the aspects intrinsic to paradigms in terms of responding to the questions that inform them.

According to Mack (2010), three research paradigms are commonly used in research namely, positivist, critical and interpretive. Key to the positivist paradigm is the use of scientific reasoning, statistical analysis and generalisable findings. This paradigm is generally implemented in science-related disciplines as knowledge is perceived as objective and credible through observation and conducting experiments to provide the ultimate truth. The critical paradigm is concerned with the political and ideological setting involved with change. It is informed by research enabling the emancipation of individuals in society. The current research does not seek to provide the ultimate truth, nor does it seek to bring about the emancipation of individuals therefore it adopts the interpretive paradigm.

The interpretive paradigm attempts to get an in-depth understanding of participants' interpretations of reality (Bunniss & Kelly, 2010). It assumes that these interpretations of reality are subjective and qualitative where their behaviours are considered distinct. According to Christiansen et al. (2010), the interpretive paradigm is used in research where people are the participants and is generally used in Social Sciences studies. It believes that educational research aims to advance knowledge and the meaning of human activities. The applicability of

the interpretive paradigm is based on first, the current research involves people (teachers) in Social Sciences. Second, the area of Social Sciences is subjective where according to Cohen et al. (2011), the interpretive paradigm aims to comprehend the subjectivity of the human experience. Linking this subjectivity to the current research, it explores in-service Life Sciences teachers' understandings of 4IR-based instructional strategies, determines their intended 4IR-based instructional strategies and assesses if their understandings and intended instructional strategies are aligned with 4IR-based instructional strategies which could be subjective to each participant.

Intrinsic to any research paradigm are its ontological, epistemological, and methodological assumptions (Guba, 1990). According to Hudson and Ozanne (1988), ontology is the nature of reality while epistemology relates to the interaction between the researcher and participants' reality (Guba & Lincoln, 1994). Lastly, methodology as the word suggests is concerned with the strategies used to determine reality (Crotty, 1998). These aspects of the interpretive paradigm are discussed in Sections 3.3.1-3.3.3.

3.3.1 Ontology

The ontological assumptions of the interpretive paradigm include that there are multiple realities dependent on other systems for meanings (Hudson & Ozanne, 1988; Lincoln & Guba, 1985). Relating this to the current research is the acknowledgement that the participants' understandings and behaviours, which could be viewed as their realities, are multiple and relative. Cantrell (2001) further comments that the multiple realities can be explored through human interactions which are dependent on different human experiences. These experiences consist of an individual's knowledge, views and the processing of such knowledge. Applying this to the current research is the identification and exploration of the different realities of the participants by first employing multiple data collection instruments and the researcher was immersed in the research process by personally interacting with the participants while collecting the data. The researcher's involvement in the research process allowed for a rich understanding of the participants' views relevant to 4IR-based instructional strategies, which ensured responding to the research questions of the current research where responses of the participants vary.

3.3.2 Epistemology

The epistemological assumption informing the interpretive paradigm is the emphasis on the understanding of a specific context with the engagement of the defined and concrete setting (Carson et al., 2001). The engagement in the specific context involved the researcher's immersion in the fieldwork stage when generating data. The researcher's interaction with the participants fulfils aspects of the interpretive paradigm's epistemological assumptions identified by Cantrell (2001) who points out that knowledge is socially constructed by the researcher experiencing the real-life setting. Experiencing the real-life setting involves interactive processes such as listening and talking found in more personal data collection instruments. Evidence of these more personal interactive data collection instruments can be found in the current research which used semi-structured interviews.

3.3.3 Methodology

In the methodological assumption of the interpretive paradigm, the researcher experiences the phenomenon to bring about meaning (Carson et al., 2001). This was demonstrated by again the researcher's immersion in the phenomenon which included administering an open-ended questionnaire, conducting semi-structured interviews and carrying out an in-depth analysis of documents (lesson plans). This immersion involved a prolonged time spent on fieldwork activities with the participants. These data collection instruments lent themselves to the methodological assumption. According to Cantrell (2001), data generation consists of text, interviews and reflective activities. This served to address the research questions and to achieve the aims of the current research as it ensured that the researcher experienced the phenomenon concerned with instructional strategies.

Further justification of the suitability of the interpretive paradigm is in its strength. In contrast to the positivist paradigm which is concerned with the assumption that there is only one truth, the interpretive paradigm in acknowledging multiple views from different individuals is more inclusive (Thanh & Thanh, 2015). A possible benefit of the current research is the production of deep knowledge through the exploration of the participants' different views.

Criticism has been levelled at the interpretive paradigm. Bernstein (1974) criticised the assumptions of the interpretive paradigm, which suggests that knowledge is shaped by multiple realities and cannot be constructed solely through a single recollection of specifics (Klein & Meyers, 1999; Walsham, 1995). Bernstein (1974) in challenging these assumptions stated that

subjective interpretation may be inadequate or confusing and often questions how meanings are negotiated. Bernstein (1974) adds that the absence of scientific methods reduces the ability to predict the outcomes. Mack (2010) adds that the findings cannot be generalised.

Morehouse (2011) responds to the criticism levelled by Bernstein (1974) by advocating for the interpretive paradigm's assumption of multiple realities resulting in a deeper understanding of a particular context. A researcher adopting the interpretive paradigm aims to develop as much understanding as possible about how the participants interact with the phenomenon. In the current research, the researcher aimed to develop a framework to enhance teachers' readiness to adopt 4IR-based instructional strategies. To do this it was necessary to engage with their understanding of 4IR-based instructional strategies and their intended instructional strategies to be adopted in the 4IR. The achievement of this aim is only possible by gaining and embracing the multiple views of the participants.

In terms of Bernstein's (1974) criticism concerned with the absence of scientific methods in interpretive research, Smith (1993) responds by arguing that there is no one path to knowledge attainment or sole process that automatically validates intellectual development. Interpretive research rarely adopts a set of standards that need compulsory observance; rather, it uses benchmarks unique to specific groups or cultures to guide and inform the research process. Concerning the claim that findings cannot be generalised, according to Klein and Meyers (1999), the validity of the interpretations from one case is not dependent on the representativeness of cases in statistical means but is instead dependent on reasonable and logical understanding through discussing the findings and drawing conclusions from those discussions.

3.4 RESEARCH APPROACH

According to Creswell (2009), research approaches are classified as quantitative, qualitative and mixed methods. In differentiating between the quantitative and qualitative approaches to research, Thomas (2010) states that both have different origins and purposes. Quantitative research methods emanate from the Natural Sciences while qualitative methods are from the Social Sciences. Thomas (2010) explains that neither research approach is better than the other. What is important is the suitability of the research methods determined by the context, aims and nature of the research.

Differences between the three types of research approaches include that:

- The world view of quantitative research is that a single reality exists while qualitative research has multiple realities.

- Quantitative research aims to determine relationships between quantifiable factors while qualitative research attempts to comprehend social conditions from participants' views.

- Quantitative research methods are rigid while they are flexible in qualitative research.

- The role of the researcher in quantitative research is that of an objective observer which is again different to qualitative research where the researcher is immersed in the research.

- In terms of generalisability, the quantitative approach posits that widespread context-independent generalisations exist while qualitative research emphasises context-bound, in-depth understandings that may not be readily generalised beyond specific contexts or cases.

- In terms of the mixed-methods approach, Creswell (2009) writes that it is a combination of both quantitative and qualitative approaches. It is concerned with more than collecting and analysing both types of data as it includes the simultaneous use of both approaches.

In tandem with the definitions supplied for the qualitative approach, more definitions are used for the justification for the suitability of the qualitative approach for the current research. Intrinsic to a qualitative approach is the naturalistic seeking of an understanding of what people have of phenomena (Denzin & Lincoln, 2003). Domegan and Fleming (2007) add that in attempting to gain an understanding, rich data is used. The qualitative approach is well-suited for educational settings like the current research, drawing from Social Sciences. It allows for a deeper exploration of everyday phenomena or issues experienced by diverse groups in their natural environments, facilitating a more comprehensive understanding.

In a qualitative approach, there is little control over the participants' understanding of the phenomenon (Hitchcock & Hughes, 1995). Creswell (2009) further writes that qualitative research requires exploring the unknown. Having little control over participants' understanding of 4IR-based instructional strategies, their intended instructional strategies and their readiness to change are identified as the unknown making the current research qualitative. Examples of the qualitative approach can be identified in the immersion of the researcher in the fieldwork in the participants' natural settings using data collection instruments which lean towards allowing them the freedom to express their opinions when generating rich textual data.

Being aware of the shortcomings of the qualitative approach is important as the researcher will be able to negate them. There is the potential for researcher bias as a shortcoming of the qualitative approach. According to Lincoln and Guba (1985), the qualitative approach

recognises the subjectivity of the researcher and requires the identification of the "biases, motivations, interests or perspectives of the inquirer" (p. 290). Other shortcomings of the qualitative approach require the researcher to be aware of the varying credibility of the participants which may impact findings; the presence of the researcher could influence the participants resulting in distorted data; and a short-term qualitative approach does not necessarily build the trust needed to obtain honest responses.

In terms of negating researcher bias, the researcher regularly consulted with the supervisor of the current research on aspects such as the research approach, data collection and analysis. The supervisor of the current research checked for any biases and advised on the elimination of any if identified. Another strategy used to negate any bias was returning the transcripts of the interviews to the participants for them to check if there was any misrepresentation of their responses. Multiple data collection instruments were used to ensure triangulation which corroborated the participants' responses, thus limiting the generation of data that could have been distorted. Finally, the fieldwork component of the current research was prolonged which established trust between the participants and the researcher allowing for honest, rich and authentic responses.

3.5 RESEARCH DESIGN

The current research guided by the interpretive paradigm and the qualitative research approach lent itself to a case study research design. Exploring the aspects of a case study serves to justify its suitability and hence its adoption.

According to Creswell (1994), the interpretive paradigm and a case study together provide for a more in-depth description and understanding of individuals' perspectives of the phenomenon in a social setting. A case study as a research design involves a single group of individuals, hence the term 'a case'. Denzin and Lincoln (2011) view a case study as allowing a researcher to acquire a deep holistic perspective of the phenomenon which enables describing, understanding and analysing it in its context. The current research explores the understanding of in-service teachers as a group in a school context which is a social setting. Therefore, the research design employed by the current research is a case study.

According to Yin (2003), a case study examines a contemporary phenomenon in its real-life setting. Ritchie and Lewis (2003) add that a case study is concerned with a diversity of perspectives that are entrenched in a definite context. The diversity of perspectives is related

to the assumptions of the interpretive paradigm concerned with there being multiple realities of individuals. The current research explored 4IR-based instructional strategies which is a contemporary subject and garnered a range of views from participants in a specific setting. The researcher envisaged that the participants would exhibit diversity in terms of their gender, age, teaching experience and qualifications. This diversity would garner varied responses making a case study suitable.

McMillan and Schumacher (2001) further comment that a case study is a detailed examination of a specific setting done over time which uses various data collection instruments. Yin (2003) adds that accessing multiple sources (participants and data collection instruments) of data is advantageous in enhancing the credibility of the research. This was done by the researcher spending an extended period in the field with the participants and analysing the data from multiple data collection instruments. Each data source represents one piece of the puzzle which comes together through their analysis providing for a deeper holistic comprehension of the phenomenon. Section 3.4 identified the qualitative research approach of the current research; one can combine it and the research design to term it a qualitative case study. The research design is termed a qualitative case study as it "provides a unique example of real people in real situations, enabling readers to understand ideas more clearly" (Cohen et al., 2011, p. 289).

Criticism has been levelled at a case study design. Although gratifying, the vast amounts of data generated from the multiple data sources make it time-consuming and difficult to manage making analysis monotonous (Baxter & Jack, 2008). Darke et al. (1998) add that prospective institutions or participants are not always willing to participate in the research. They state that due to this, first, the reporting of the findings may be challenging and second, justifying the validity of the study is sometimes difficult. Hence, several researchers have labelled a case study as lacking thoroughness (Baskarada, 2014; Darke et al., 1998; Yin, 1994).

Responding to the criticism concerned with the management and analysis of case study data, Zainal (2007) asserts that the detailed and deep knowledge obtained from the data aids in explaining actual experiences relevant to the study. A vast amount of data assists in identifying and explaining the intricacies of the participants' experiences that are difficult to capture in experimental or survey data. The researcher does not encounter the situation of having a limited amount of data that could diminish the findings of the current research. Rather, the researcher has a volume of in-depth knowledge that will increase the richness of findings.

Concerning case studies lacking comprehensiveness. Merriam (1998) argues that since a case study occurs within a fixed system, critical issues about its design and application contribute to its comprehensiveness. This design and application include using a theoretical framework, development of research questions and determining criteria for analysing the data. Considering this reasoning, the researcher expanded its comprehensiveness by using a theoretical framework which identified and merged relevant theories. By doing this, the researcher was constantly aware of the research questions when reviewing literature which generated criteria for the interpretation and analysis of data.

Another criticism of a case study identified by Baxter and Jack (2008) is the tedious task of reporting due to the intricate nature of the phenomenon that needs a succinct report that is simply understood by the reader. The report aims to capture the core of the phenomenon in such a way that it places the reader in the context of the research as if they were there. Yin (2003) suggests methods that can be used when writing an effective case study report. These include the report being linear, comparative, sequential, theory developing or sequenced processing. According to Baxter and Jack (2008), case study reporting is chiefly concerned with sequentially relating a story, therefore, making there no right or wrong way of doing it. The researcher addressed the criticism by sequentially reporting the data in doing so ensuring the report reflects the authentic data generated from the in-service Life Sciences teachers in an attentive and succinct approach reflective of the research questions.

The fact that a case study is non-representative and lacking in statistical generalisability is another critique levelled at it. Merriam (2009) writes that several positivist proponents raise concerns regarding the generalisability of a case study. The key to this is that its findings cannot be generalised or scientifically verified; therefore, it is short on comprehensiveness and reliability. Piekkari et al. (2009) argue that case study research has been needlessly diminished by comparing it with statistical research of the positivist paradigm and it is therefore, viewed as weaker than approaches that represent comprehensiveness. Denzin and Lincoln (2000) counter this criticism by arguing that "looking at multiple actors in multiple settings enhance generalisability" (p. 193). Yin (2003, 2009) adds that generalisations cannot be restricted to statistics as this would limit its ability to explain what they represent. Merriam (1985) also argues that statistical and quantitative views of generalisability should not be used in qualitative research but rather the emphasis should be on the research being credible and conformable.

Researcher bias is another criticism levelled at a case study. Cornford and Smithson (1996) state that there could be researcher bias emanating from multiple understandings of the complex data generated. Darke et al. (1998) claim that a researcher may consciously or subconsciously influence the findings to suit a particular interest because of their personal beliefs and assumptions. According to Walsham (1995), biases stemming from the researcher's understanding are difficult to avoid because the researcher shares perceptions and understandings with the participants.

Klein and Meyers (1999) argue for the principle of dialogical reasoning to counter researcher bias. This involves the researcher encountering personal preconceptions during the initial stages of the research design and, as the research progresses, eradicating these preconceptions through the reconceptualisation of concepts and the development of understanding. Vital to this is that the researcher should record the process of interpretivism, appreciate its philosophical underpinnings and reveal its pertinent strengths and weaknesses.

3.6 RESEARCH METHODS

This Section engages with the research methods used in the current research by presenting a description of the selection of participants, the data collection instrumentation, the data collection procedure, the method used in analysing the data and the measures that were implemented to secure the trustworthiness of the results.

3.6.1 Population and Sampling

According to Latham (2007), in any research, certain entities come under scrutiny namely individuals, locations or items placed under the microscope. Studying each of these entities is an undertaking that most researchers do not have the time or money to facilitate. Therefore, researchers select a representative number within these entities, called a sample. Frey et al. (2000) define a sample as a sub-group of the population that represents the features of a population. Teddlie (2007) confirms this by stating that the selection of people, places or things from which data is generated is called a sample.

Cohen et al. (2007) posit that quality research is not only dependent on the suitability of the procedure and instrumentation but also depends on the sampling approach adopted by the researcher. Glaser (1978) adds that a researcher approaches possible groups that they believe will maximise the possibility of obtaining data relevant to their study. Considering the

definitions, a sample is concerned with a description of who is going to make up the specific group of individuals as representatives of the entire group. Onwuegbuzie et al. (2008) ascribe value to sampling by stating that it is a vital step in any research design as the trustworthiness of the study in terms of its findings is reliant on whom the data was generated from.

Quantitative research sampling procedures are clearly outlined which is not the case for qualitative studies (Coyne, 1997). However, Curtis et al. (2000) provide a few important characteristics of qualitative samples. These include that, in qualitative research, the technique of obtaining samples is not directed by the statistical probability of selection, samples are small generating a rich account, and the process of selecting a sample is initiated by the theoretical framework developed from the research question. The sample also allows for analytical assumptions where comprehension of the phenomenon is developed because of the novel or prevailing theories about it. Miles and Huberman (1994) also proposed features that a sample should cover. These include that the sampling method should relate to the conceptual framework and the research questions of the research. The sample should obtain deep information on the phenomenon and produce authentic explanations. The sampling procedure should maintain ethical procedures and feasibility is the consideration of costs and accessibility. The characteristics and features to consider in the sample of a study proposed by Curtis et al. (2000) and Miles and Huberman (1994) respectively influenced how the researcher approached the method of sampling in the current research. Being aware of these characteristics and features enabled the sampling method to inspire the data generation step. When choosing the sampling method, consideration was given to the phenomena of teacher readiness to change, the 4IR, instructional strategies and the research approach and design.

3.6.1.1 Sampling procedures

Latham (2007) recognises two sampling categories, namely, probability and non-probability sampling. The adoption of either one is dependent on the nature and aims of the research.

- Probability sampling: Random samples are often used when referring to probability samples which are regarded as the most accurate sampling method as they can be used to generalise the findings from the sample to the entire population. According to Teddlie (2007), this category of sampling is distinctive of quantitative research studies and therefore was not considered for the current research.

- Non-probability sampling is generally adopted in qualitative research as the purpose of the sample is to provide insight into the views and actions of the participants (Marshall, 1996). According to Cohen et al. (2007), the size of a sample is guided by the type of research study. Marshall (1996) states that in qualitative research a small sample size is generally chosen as a large sample will result in additional biases and a sample size is deemed sufficient if it answers the research questions. Hennink et al. (2011) add that a qualitative study requires a small sample as by its very nature, it relates to a comprehensive investigation of topics that a small sample permits. The use of a non-probability sample produces deep, thorough explanations from a small sample that can generate comprehension of the phenomenon of the study.

Four types of non-probability sampling exist.

- Purposive sampling relates to the selection of units, groups, or individuals for the explicit aim of answering the research questions of the study (Teddlie, 2007). According to Morse (1991), purposive sampling is the selection and engagement of individuals whom the researcher views as having extensive general knowledge of the phenomenon or having experienced it. This is in line with Maxwell (1997) who defines purposive sampling as the "particular settings, persons, or events that are deliberately selected for the important information they can provide that cannot be gotten as well from other choices" (p. 87). Christiansen et al. (2010) add that purposive sampling involves targeting a specific group that represents itself.
- Latham (2007) explains that convenience sampling is concerned with the ease of accessibility of the participants. The sample being conveniently selected, Cohen et al. (2007) define convenience sampling as relating to choosing the most easily available individuals as participants until a sufficient sample size is established.
- Quota sampling occurs when there is a division of the population into sub-groups where a criterion of age, gender, race or ethnicity is used to non-randomly select groups (Latham, 2007).
- Snowball sampling is adopted when a specific group of individuals has been proposed however they cannot be identified (Frey et al., 2000). This type of sampling relies on an individual who has the means to connect with this group due to the characteristics and knowledge they possess. Group members who have already been identified can approach their network to source participants who have the required traits.

Considering that the current research is qualitative adopting the interpretive paradigm and a case study, non-probability sampling is best suited for answering the research questions to understand the phenomenon. From the various types of non-probability sampling, both purposive and convenience sampling were selected. Integrating the two facilitates the generation of in-depth data.

- Purposive sampling

Adopting purposive sampling allows the researcher to be selective in choosing who is to participate in the study. In line with the definitions supplied for purposive sampling by Christiansen et al. (2010); Maxwell (1997) and Morse (1991), the participants of the current research were in-service Life Sciences teachers representing themselves having the knowledge of the Life Sciences curriculum and expertise in the discipline of teaching it. Making them well-suited to generate rich authentic data to respond to the research questions and aims of the current research. According to Klein and Meyers (1999), rich data stems from purposive sampling and facilitates qualitative research.

- Convenience sampling

In terms of convenience sampling, Marshall (1996) writes that it is a sampling method that is not costly regarding time and money. Time is not expended on searching for participants as those that are nearby are selected. Also, the researcher does not need to spend an exorbitant amount of money on transport and communication facilities as the participants are again accessible. In the current research in line with the purposive and convenience sample, the researcher was aware of the individuals who would be able to address the research questions, and who would be easily accessible therefore time and money were saved. Access to the participants was due to the researcher having had healthy professional interactions with many of the participants in the past. This ensured convenience as an excellent rapport was developed with the participants which ensured accessibility to them. This rapport allowed the participants to feel relaxed and not be intimated when responding to questions posed. Therefore, their responses were authentic and allowed for a deep description of their thoughts which ultimately ensured meaningful data.

- Critique of purposive and convenience sampling

As with other aspects of research, criticism has been levelled at purposive and convenience sampling. There is the possibility of the analysis of the data of non-probability sampling being time-consuming as by its nature the data is comprehensive (Cohen et al., 2007). This dealt with the researcher's awareness of the features of qualitative research. At the onset, the researcher appreciated the fact that there would be volumes of data and prepared to analyse the data in a disciplined manner by allocating the time to do so. The researcher welcomed the generation of this deep and rich data from the participants as a product of it was a deeper understanding of the phenomenon.

There is also the view that convenience sampling may result in the researcher becoming slack by selecting any individual that just matches the criteria of the envisaged sample and therefore lacks credibility because of poor data quality (Marshall, 1996). This criticism was addressed by the researcher cautiously selecting the participants which involved arranging meetings to determine their degree of understanding of the phenomenon.

Cohen et al. (2011) add to the criticism of convenience sampling on two more fronts first, in terms of researcher bias as he or she might eliminate individuals who also have the applicable understanding of the phenomenon and second, it fails to deal with issues concerned with the participants representing the population. In dealing with potential researcher bias when selecting participants, the invitation to participate in the current research was extended to as many teachers as possible in the field of Life Sciences. However, some declined the invitation due to work and family commitments. In countering the representation criticism, the participants display diversity in terms of their gender, age, teaching experience and qualifications. They were, therefore, representative of the greater teacher population as it also exhibits such diversity.

- Snowball sampling

In the interest of securing the trustworthiness of the current research by providing a thick description is the acknowledgement that snowball sampling to a limited degree was also adopted as the fieldwork progressed. Snowball sampling occurred during the researcher's interactions with one of the consenting participants who indicated that she was able to connect the researcher with prospective participants who met the current research's sample characteristics. These characteristics were their understanding of the phenomenon, as they were

Life Sciences teachers and were accessible in terms of their location. All other aspects related to an individual consenting to participate in a research study were followed even in the case of this snowball sampling. Therefore, the sample for the current research consists of two cohorts. Collins (n.d.) defines a cohort as being a group of people who share a common characteristic. The common characteristic shared by participants found in one of the cohorts of the sample was that they were invited to participate in the current research by the researcher approaching the school and then duly obtaining their informed consent. The common characteristic of the other cohort of the sample was that it consisted of individuals who were selected by way of snowball sampling.

3.6.1.2 Participant profiles

The sample of the current research consists of 10 Life Sciences teachers from the Pinetown educational district in the province of KwaZulu-Natal, South Africa. Section 3.6.1.3 provides more information on the location. In the interest of ensuring ethical considerations when conducting research, the participants were assigned pseudonyms to provide anonymity. Table 3.1 presents an outline of the participants.

Table 3.1: An Outline of the Profiles of Participants

Participant	Gender	Age	Race	Years of teaching experience	Highest Qualification
Kate	Female	41-50	Coloured	21-25	Master of Education
Emma	Female	31-40	Coloured	16-20	Bachelor of Education (Honours)
Charlotte	Female	51-60	Coloured	+25	Bachelor of Arts (Education)
Sophia	Female	41-50	Black	21-25	Bachelor of Education
Amelia	Female	20-30	Indian	1-5	Bachelor of Education
Mia	Female	41-50	Coloured	21-25	Bachelor of Education (Honours)
Peter	Male	20-30	Black	1-5	Postgraduate Certificate in Education

Participant	Gender	Age	Race	Years of teaching experience	Highest Qualification
Ava	Female	31-40	Coloured	6-10	Bachelor of Education (Honours)
Isabella	Female	41-50	Black	16-20	Advanced Certificate in Education
Olivia	Female	51-60	Indian	+25	Advanced Certificate in Education

Table 3.1 provides the characteristics of the sample of the current research which include that females significantly outnumbered males in the sample. This dominance of females in the sample is consistent with the South African context as female teachers disproportionally outnumber males in schools (Davids & Waghid, 2020). Other characteristics of the sample include a range in ages, teaching experience and qualifications demonstrating a degree of diversity of the sample. It is acknowledged that the diversity of the sample is not fully secured in terms of race as there are no white participants in the sample. This was a result of convenience sampling as no white teachers were teaching in the schools that were approached. Schools that were convenient to access in terms of their proximity to the researcher which was cost-effective as the researcher did not need to spend an exorbitant amount of money on transport.

The use of ranges for the participants' ages and teaching experience contributes to securing the anonymity of the participants as supplying an explicit age and teaching experience could lead to their identification. This could occur as other teachers of the same gender, age, race and teaching experience range were approached to participate from which the schools the participants hailed. If explicit information was supplied, individuals who observed the researcher's presence might be able to identify the participants after reading the current research.

3.6.1.3 Location

Discussing the location of the current research provides context as it adopts an interpretive paradigm and is a qualitative case study. The adoption of this paradigm, research approach and design involves the understanding of the multiple realities of individuals in a specific context.

The discussion concerned with the location of the current research is firstly done in a broad sense and progresses to a narrow one. The broad sense is concerned with the province in which it takes place. The narrow sense involves the educational district and the schools the participants operated in. Secondly, the discussion justifies the selection of the location.

The current research was conducted in the province of KwaZulu-Natal which is situated in the southeast of South Africa along the shoreline of the Indian Ocean. In terms of size, six out of the nine provinces of the country are larger. Even though it is one of the smaller provinces in the country, in 2022 it had the highest number of learners attending school (Statista, 2024). The selection of KwaZulu-Natal as the province to conduct the current research is informed by the number of learners who wrote Life Sciences in 2020 and the results. In doing so, the sample is concerned with the number of learners the participants teach and the range of results that such learners achieve. First, in identifying the province, the 2020 National Senior Certificate School Subject Report, reported that 319 228 learners wrote Life Sciences across the nine provinces of South Africa. KwaZulu-Natal accounted for 73 663 of the learners who wrote nationally which accounts for 23% of the learners who wrote Life Sciences in 2020 and the most compared to other provinces.

The district in the province where the teachers practised had the fifth most learners out of 12 districts. This district is ranked third in terms of its results, relating to learner achievement above 30%, within the group of the five districts with the largest number of learners who wrote. Furthermore, schools within the district exhibit differences in terms of the number of learners who wrote Life Sciences and the range of results. For example, the number of learners who wrote ranged from 4 to 204 learners and learners' achievement ranged from 13.3% to 100%. Therefore, the criteria used to select the sample represent teachers who encountered many learners who represented a range of achievements. This represented the greater population as other Life Sciences teachers also encounter varying numbers of learners and learner achievements. It was hoped that their participation would better equip them to handle the issues around change, the 4IR and their instructional strategies by way of their exposure to these issues through the current research. Ultimately this exposure will contribute to the lives of their current and future learners as they will have a better understanding of the issues which inform their decisions concerned with instructional strategies.

The five schools in the current research are in suburbs that were previously classified as disadvantaged. Three of these five schools made up the cohort, as previously explained in

Section 3.6.1.1 where the schools in which they operated were approached leading to an invitation for their participation. Two of these three schools were part of the same quintile category namely, Quintile 4 while the other was categorised as a Quintile 3 school. A ranking system of schools comprising five quintiles was developed to improve equality in terms of the funding of education. It was envisaged that the ranking schools would result in the fair distribution of funds between poor and wealthy schools. However, according to van Dyk and White (2019), the implementation of this ranking system has not proved to be effective.

The ranking system is informed by the unemployment and literacy rate of the community in which the school is based. A school which is ranked as a Quintile 1 school is deemed to be serving a poor community needing more funding, while a school ranked as a Quintile 5 school is deemed to be serving a wealthy community needing less funding. Quintile 1, 2 and 3 schools are non-fee-paying schools where learners do not pay any school fees. Essentially each quintile receives different funding from the government which is relative to the community in which they are located.

The two schools that made up the other cohort of participants which involved snowball sampling were Quintile 4 schools. Therefore, in the current research, four of the five schools were Quintile 4 schools, and one was a Quintile 3 school. Schools in Quintiles 1 to 3 do not charge fees and receive greater government funding per student compared to those in Quintiles 4 and 5. The latter are fee-paying schools, based on the premise that parents can afford the fees, and thus, need less financial support from the government than lower-quintile schools.

The explanation of the ranking system of schools when exploring the location is relevant. The relevance is that teachers' readiness to adopt 4IR-based instructional strategies is to a degree informed by the availability of resources. Okello and Kagoire (1996) acknowledge that a lack of teaching and learning resources leads to the unsuccessful implementation of a curriculum. Moloi and Mhlanga (2021) add that South Africa is not ready for the 4IR as many schools do not have the technologies to facilitate learning. These points are relevant and the ranking system of schools as the provision of resources is linked to funding.

3.6.2 Data Collection Instruments

Generating data is a process of gathering information from a sample consisting of participants with the aim of understanding, analysing, and interpreting their actions and experiences relative

to the questions of the study (Cohen et al., 2011). Kaplan (1964) adds that methods of producing data are tools and systems used to obtain explanations from participants.

Multiple data collection instruments are used in a case study, and this contributes to its strength. Yin (2003) writes that the use of multiple data collection instruments is a trademark of case study research that achieves data credibility. Typical data collection instruments for a case study include interviews, observations, document analysis and questionnaires. Three data collection instruments, namely, an open-ended questionnaire, a semi-structured interview and document analysis were used to address the research questions of the current research. The use of these data collection instruments is in line with a case study as they are multiple and commonly used. The use of multiple data collection instruments provides for the generation of rich information leading to a deep understanding of the phenomenon. The various data collection instruments support the concept of triangulation which ultimately promotes the trustworthiness of the findings.

The use of different types of data collection instruments adds to the current research making a new contribution to research on 4IR-based instructional strategies. The combination of instruments makes the current research unique. The data collection instruments were designed in alignment with the main research question and the research sub-questions to achieve the aims of the current research stated in Sections 1.3 and 1.5 respectively. Therefore, there is a layered approach to answering the main research question in terms of the data collection instruments. For example, the data collection instruments contribute to the findings. These findings are relevant to a particular research sub-question and contribute to the findings of other research sub-questions. Table 3.2 is a summary of the data collection instruments contributing to the findings for a particular research sub-question. It also outlines which research sub-question/s contribute to the findings of other research sub-questions.

Table 3.2: Summary of the Data Collection Instruments Related to the Research Sub-Questions

Research sub-question	Data collection instruments which generate data	Research sub-question/s contributing to findings of the research sub-question found in the first column of the table
1.	• Open-ended questionnaire • Semi-structured interview • Document analysis	Research sub-question 2
2.	• Open-ended questionnaire • Semi-structured interview • Document analysis	
3.	• Open-ended questionnaire • Semi-structured interviews • Document analysis	Research sub-questions 1 and 2
4.	• Open-ended questionnaire • Semi-structured interviews • Document analysis	Research sub-questions 1, 2 and 3

Sections 3.6.2.1–3.6.2.3 discuss the data collection instruments used in the current research in the sequence they were administered. Each section pertains to a particular data collection instrument and identifies its structure and how the data collection instrument was used to generate data that would respond to the relevant research sub-question/s.

3.6.2.1 Open-ended questionnaire

The open-ended questionnaire generates data that explores to varying degrees all the sub-questions of the current research. A questionnaire is valuable for obtaining survey information that provides organised data and can be completed by the participant in the absence of the researcher. This characteristic of a questionnaire conflicts with research that is qualitative and adopts the interpretive paradigm as survey information involves responding to close-ended questions. However, in designing the questionnaire, open-ended questions were included,

ensuring that the questionnaire was fit-for-purpose. The term fit-for-purpose is concerned with an item being well-suited to perform its selected purpose (Oxford University Press, n.d.b.). The inclusion of open-ended questions provides for the generation of data that is more detailed which is in line with qualitative research. Further, the justification for selecting an open-ended questionnaire assists in acquiring an understanding of individuals' lived experiences (Christiansen et al., 2010). These experiences inform the understanding of the participants of the phenomenon under investigation.

When compiling a questionnaire, the researcher must ensure that it produces the data required to respond to the research questions and relies on language that is easily understood (Christiansen et al., 2010). Contributing to the trustworthiness of the open-ended questionnaire is that, in designing the open-ended questionnaire, there was regular consultation with the supervisor of the current research which eliminated any bias the researcher might have had. These regular consultations resulted in the effective development of the open-ended questionnaire and how the concept of investigator triangulation was secured (Lincoln & Guba, 1985; Sim & Sharp, 1998). Where investigator triangulation is applied in terms of the supervisor being in part a second individual is involved in the research.

In terms of the language of the open-ended questionnaire being easily understood, English is used which addresses the disadvantage associated with a questionnaire requiring participants to be literate in the language used (Christiansen et al., 2010). All the participants taught in English medium schools ensuring that they were well-versed in the language. Added to this, the open-ended questionnaire was piloted before being handed out to ensure that the questions were accessible to the participants. This piloting activity involved other teachers in science and mathematics reviewing the questions to be posed. The reason for choosing these teachers was that they shared commonalities with the participants regarding their exposure to the language of science.

The open-ended questionnaire (Appendix G) consisted of three sections. Section 1 identified the biographical details of the participants namely their gender, race, age, teaching experience, qualifications and exposure to instructional strategies and the 4IR. The inclusion of questions related to the two latter aspects assisted in ascertaining if the participants were aware of them. It was envisaged that their level of awareness influences their understanding of 4IR-based instructional strategies. Ascertaining their understandings and therefore their attitudes towards the 4IR is in line with the theory that underpins this research as explored in Chapter 2. These

questions explored whether instructional strategies were covered in their qualifications, if subject-specific meetings or workshops were organised by the DBE and if they individually or their school were affiliated with professional bodies or subscribed to Life Sciences education publications.

Section 2 is divided into two parts. Part A provided insight into the participants' understandings of education in the 4IR. It is informed by the features of quality education (WEF, 2020). These features included the skills that need to be developed by learners in the 4IR through the content and the learning experiences that will develop such skills (Section 2.2.4). The format of Part A required the participants to respond to a Likert-type scale consisting of statements based on the skills and the learning experiences in the 4IR. Quantitative studies are generally characterised by these types of scales; however, they also determine the participants' understanding of education in the 4IR. Bell (2005) states that "scales are intended to help researchers discover strength of feeling or attitude" (p. 167). Maree (2007) characterises a Likert-type scale as having only options 'agree' or 'disagree'. In designing the Likert-type scale for the current research to generate honest and authentic data, the option of 'uncertain' was included. The nature of the statements makes completion of the questionnaire quick and easy. This was convenient for participants as they did not have an abundance of free time available to them because of their occupation.

This part of Section 2 contributed to findings related to the research sub-question on the participants' understanding of 4IR-based instructional strategies. An understanding of the skills to be developed by learners in the 4IR and its learning experiences enable teachers upon reflection to select the appropriate instructional strategies. The logic informing the identification of the participants' understandings of education in the 4IR is based on the view that it is this understanding that will influence their understanding of 4IR-based instructional strategies.

Part B of Section 2 generated data that responded to the research sub-question on the instructional strategies the participants intended to adopt in the 4IR. Participants were required to indicate with an X which instructional strategies they intended to adopt. The range of instructional strategies that frame the current research was listed based on the literature on the different types of instructional strategies (Akdeniz, 2016; Nuraidah et al., 2021). To gain more insight into their understanding of their intended 4IR-based instructional strategies the

participants were provided with a space to support their choice. This part also contributed to findings related to the participants' understanding of 4IR-based instructional strategies.

Section 3 generated data that not only informed the findings of several of the research sub-questions but also secured the triangulation of data generated from the other data collection instruments. Questions in this Section engaged with the participants' understanding of the 4IR, the term instructional strategies and the 4IR influence on their teaching practice. These questions contributed to the findings of the research sub-questions on the participants' understanding of 4IR-based instructional strategies and their intended instructional strategies. Ascertaining the participants' views on the influence of the 4IR on their teaching practice indicated their intended instructional strategies which revealed their understanding of 4IR-based instructional strategies.

The remaining questions of Section 3 explored the other aspects of the theory that underpinned the current research. The questions were informed by the RRCM (Holt et al., 2007), the UTAUT (Venkatesh et al., 2003) and forces that shape an individual's attitude (Kondakci et al., 2017). These were part of the theoretical framework and therefore contributed to determining the readiness of the participants to adopt 4IR-based instructional strategies to develop a framework to enhance their ability to adopt 4IR-based instructional strategies. For example, the dimension of the appropriateness of the RRCM (Holt et al., 2007) was explored by asking the participants if they felt the influence of the 4IR on their teaching practice was necessary. They were also asked what resources they currently used in their teaching practice which also spoke to the appropriateness as the questions were concerned with the difference between what they currently did and the envisaged behaviour where 4IR-based instructional strategies used technology. Another dimension explored was that of self-efficacy which is concerned with an individual belief in their ability to perform a new activity (Gist & Mitchell, 1992). Concerning self-efficacy, the participants were asked if they felt they were ready to adapt to the 4IR.

3.6.2.2 Semi-structured interviews

According to Maree (2007), an interview enables one to "see the world through the eyes of the participants" (p. 87). It strives to obtain in-depth information from the participants about the phenomenon by addressing predetermined questions and aims of a study (Savenye & Robinson, 2004). Interviews are systematic in the way people talk and listen where information is gathered

while communicating (Kajornboon, 2005). Nieuwenhuis (2007) further commented that it is a two-way conversation that enables the researcher to ask questions to learn about an individual's ideas, beliefs, views and behaviours. Wahyuni (2012) confirms this with the assertion that its key attribute is that an interview enables the sharing of the participants' accounts, understandings and views related to the phenomenon of a study. The participants as experts in the discipline revealed their feelings through discussions during the interview.

These definitions complement the view held by Christiansen et al. (2010) that an interview is a method widely applied in interpretive research. Because the current research is qualitative and reinforces its suitability, an interview as a two-way flow of communication produces greater interaction between the researcher and participant in building knowledge about the phenomenon (Kajornboon, 2005). Interviews enable the researcher to establish a relationship with the participants of a study (Leedy & Ormrod, 2001). Such a relationship allows for the generation of more data as participants will be comfortable explaining their responses.

According to Kajornboon (2005), there are four types of interviews, namely, structured, semi-structured, unstructured and non-directive. Corbetta (2003) writes that structured interviews, also known as standardised interviews, are when identical questions are posed to all the participants. They follow a logical structure and are regarded as inflexible because probing is not possible. Savenye and Robinson (2004) state that semi-structured interviews are generally used in qualitative research and, in contrast to structured interviews, do not follow a rigid structure. They provide a tentative structure to interview the participants. According to Cohen and Crabtree (2006), the interviewer is not restricted by the interview schedule and may choose to deviate to follow topical trajectories. This deviation is made possible by probing which is a key aspect of semi-structured interviews. The aspect of probing suggests that the researcher might contemplate adding questions to obtain clarity in responses. Such probing aids in obtaining qualitative data in the form of thick descriptive information.

An unstructured interview implies flexibility and casualness in the way participants are anticipated to respond. The participants communicate freely as the interviewer does not adhere to a schedule or guide. Lastly, in non-directive interviews, there is no predetermined topic to engage with. In contrast to the other three types of interviews, in a non-directive interview, the participant leads the conversation rather than the interviewer who simply listens. This lack of direction could hinder the decoding and analysis of the data.

In considering the features of the types of interviews, a face-to-face semi-structured interview was selected for the current research. The unique features of a semi-structured interview are suitable for obtaining detailed information as it establishes a conducive environment, one that encourages the participant to be free and open. According to Cohen and Crabtree (2006), semi-structured interviews create a relaxed environment that allows participants the freedom to express themselves resulting in reliable, comparable qualitative data. To illustrate the participants in the current research being free, open, relaxed and comfortable in expressing themselves to generate rich authentic textual data is a response by Amelia. Her honesty is apparent when she explains:

> *"To tell you honestly, I had no idea about this until you had given me that first questionnaire and that's when I went and read about it. So, I'm not going to lie, I actually forgot what it means and what's it about."*

Conducting semi-structured interviews allows for the development of a plan for the interview with limited control regarding the responses of the participants. This suggests that a tentative structure does not limit the potential to discover rich and interesting data that can be relevant to a study. The presence of probes allows the interview to be flexible and to develop organically with the option of adding questions when clarity is needed.

An interview schedule consisting of open-ended questions (Appendix H) was developed to avoid restricting the participants' responses. The open-ended questions were piloted before the semi-structured interview with the participants. This piloting activity involved other teachers in science and mathematics reviewing the questions to be posed ensuring that the questions were accessible to the participants. Like in the open-ended questionnaire, the reason for choosing these teachers was that they shared commonalities with the participants regarding their exposure to the language of science.

These open-ended questions were informed by the relevant literature reviewed and the theoretical framework of the current research. This exposed, further probed and explored teachers' understandings, their intended adoption of 4IR-based instructional strategies and their readiness for change. For example, the opening of the interview schedule engaged the participants' understanding of the 4IR, the skills they believed individuals needed to acquire in the 4IR, whether they thought the 4IR would influence education, whether they had instructional strategies for the 4IR and how they normally reacted to change. The interview

schedule continued with further engagement on the participants' views of how the 4IR influenced their instructional strategies. This engagement was informed by the theoretical framework of the current research. For instance, the dimensions of the RRCM (Holt et al., 2007) and the aspects of the UTAUT (Venkatesh et al., 2003) were explored in the rest of the semi-structured interview which contributed to findings related to the participants' readiness to adopt 4IR-based instructional strategies.

3.6.2.3 Document analysis

Document analysis is defined as "a systematic procedure for reviewing or evaluating documents both printed and electronic computer-based and Internet transmitted" (Bowen, 2009, p. 27). According to Blundell (1998), document analysis is valuable for generating qualitative data. Cohen et al. (2007) further comment on the importance of documents being sources of evidence for a research study. Creswell (2012) adds that valuable information is obtained from documents assisting the researcher in understanding the central phenomenon in a qualitative study. According to Corbin and Strauss (2008), it produces significance and enhances understanding. The analysis of the participants' lesson plans enhanced understanding of the central phenomenon of the current research which is the readiness of teachers to adopt 4IR-based instructional strategies.

The analysis of documents provided data for new findings, and more understanding or agreement with findings from other data collection instruments. A qualitative researcher uses different data collection instruments to corroborate and sustain findings (Yin, 1994). This speaks to triangulation as document analysis in the current research was employed in combination with the other data collection instruments to enhance the credibility of the findings. Through triangulation, biases are reduced as findings are substantiated by data generated from across the data collection instruments which would not have been possible if the current research relied on a single data collection instrument. The lesson plans provided data from teachers relevant to instructional strategies at the school level.

The lesson plans identified consistencies and inconsistencies in the participants' understandings established in the other data collection instruments and the instructional strategies they are currently practising. One of the dimensions concerned with the readiness to change is the appropriateness of the change which relates to the difference between the present situation and the envisaged one (Holt et al., 2007). This could be related to the resources

available for the change to be implemented. The participants could be adopting 4IR-based instructional strategies which points to a certain level of understanding.

All the participants provided an already prepared and used lesson plan. This is in line with Grix (2001) who stated that documents are compiled with specific aims. Bowen (2009) asserts that researchers generally review existing documents. The participants' lesson plans were designed with a specific aim and were used to teach a lesson. The participants supplying an already taught lesson plan enhanced the credibility of the data. The lesson plan sought to generate data that would ascertain the participants' current teaching practices concerning their instructional strategies. The participants were also given the option of completing a lesson plan template (Appendix I) issued to them. The design of the template allowed participants to indicate the applicable information with an X making it user-friendly. For example, participants indicated which resources they used for the lesson. The template also provided the participants with space for textual information which explained their instructional strategies.

The option of supplying a lesson plan already designed and completing a lesson plan template speaks to flexibility, ensuring convenience for the sample. The participants were able to select the option that would be convenient to them. It was envisaged that this convenience would generate rich, authentic data that would be used for a deep understanding of the phenomenon of this study.

There are several advantages to using document analysis in research. The advantage of providing triangulation in the interest of credibility and trustworthiness has been discussed. Bowen (2009) states that it saves time in terms of availability as in the case of the participants providing a lesson plan already designed was easily accessed both by the participants and the researcher. According to Yin (1994), documents enable the researcher to generate inferences because of the precise iterations they possess. This is linked to the documents being analysed without being transcribed as they have been previously prepared in the form of words and print (Creswell, 2008). This reinforced trustworthiness as the researcher was able to check the lesson plans numerous times. In this activity, confidentiality was maintained when handling the lesson plans by ensuring the name of the participant was changed.

3.6.3 Data Collection Procedure

The fieldwork component of the current research commenced with a scheduled information session with the prospective participants. In this session, the researcher explained the various

data collection instruments. When a prospective participant was unavailable to attend, the researcher arranged to meet them individually. At the information session, a resource pack was handed out to the prospective participants who indicated they would participate in the current research. This resource pack contained the open-ended questionnaire, a cover letter (Appendix F) and a lesson-plan template. The participants were encouraged to seek clarity on any aspects of the various data collection instruments found in the resource pack which might be confusing. Figure 3.3 represents the sequence of the data collection instruments that were administered.

Figure 3.3: The Data Collection Procedure
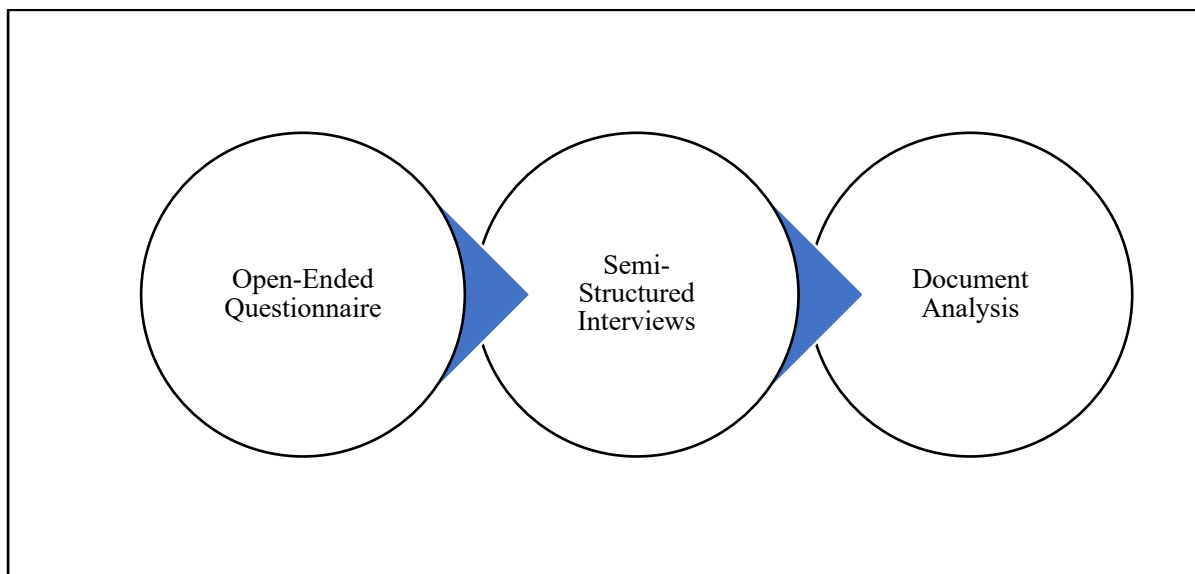
3.6.3.1 Open-ended questionnaire

The participants were informed they could self-administer the open-ended questionnaire. It was anticipated that this would elicit honest responses as the researcher's presence could have intimidated the participants as well as made the completion of it convenient.

- Dealing with the challenges of open-ended questionnaires

Christiansen et al. (2010) identify the disadvantages of using a questionnaire which are primarily concerned with it being posted to participants. First, when posted, the researcher is not present to check whether the participants understand the questions and second, there is often a low return rate. Other disadvantages of a questionnaire include that the participants may supply responses that they think the researcher wants.

The disadvantages of using a questionnaire did not influence the current research as it was not posted to participants. Hence, there were no issues with participants not understanding what they needed to respond to as the researcher was on hand to clarify any misunderstandings. The researcher handing the questionnaires out personally and being available to collect them once completed on an agreed-upon date meant that all the questionnaires were returned. The participants were also given the option of contacting the researcher if they completed the open-ended questionnaire before the agreed-upon date. The disadvantage of participants supplying responses they thought the researcher would want was handled on two fronts. Initially, the researcher played a direct role in outlining the research scope to the participants before they committed to participating. Second, the researcher's continuous presence during the data collection phase facilitated the establishment of a trust-based relationship with the participants. This relationship ensured that the participants' responses to the open-ended questionnaire were authentic. This trust relationship was further enhanced by the researcher having previously had professional relationships with several of the participants which once again facilitated the collection of valuable data.

3.6.3.2 Semi-structured interview

All the participants accepted an invitation to participate in a semi-structured interview which lasted between 30 and 45 minutes. The participants and the researcher negotiated a date for the semi-structured interviews depending on their availability. The semi-structured interviews were valuable as they clarified responses from the open-ended questionnaires which facilitated a deep understanding of the participants' responses. This is in line with Greeff (2005) who asserted that interviews were the primary method of generating data in qualitative research.

The researcher developed an interview schedule to guide the interviews which ensured they were not rigid but rather flexible allowing for an organic discussion. This saved time as it provided direction for the interview. The participants still had the opportunity to explore relevant issues which were triggered by questions in the interview schedule.

A probing strategy clarified ambiguities that the participants might have communicated through their responses to the open-ended questions. This probing strategy included detail-orientated probes, elaboration probes, and clarification probes (Maree, 2007). The detail-orientated probes according to Maree (2007, p. 88) aided in understanding the "what" and "why" of responses supplied by the participants. For example, at certain stages of the interviews, the

researcher gently asked participants to substantiate their responses. The elaboration probes assisted in gaining more detail. For example, the researcher once again gently asked the participants if they could further explain their response or engaged with the participant on their response which resulted in the participant providing more substance or description to their initial response. Clarification probes verified understanding of responses. For example, after a few responses, the researcher summarised, the responses already explored before moving on with the interview. All semi-structured interviews were audio-recorded, upon consent, and transcribed to facilitate data analysis informed by precise transcripts providing valuable qualitative data.

- Dealing with the challenges of interviews

Power relations influence the interviewing process (Christiansen et al., 2010). If the interviewer (researcher) is superior to the interviewee (participant) within an institution, this may influence the responses the interviewee provides; for example, a principal being the researcher and interviewing a teacher working at the school. Interviews inherently involve the interviewee reporting on their own experiences or beliefs. Sometimes the interviewee provides information that misrepresents the truth. In response to these disadvantages the researcher of the current research is not employed by the KwaZulu-Natal Department of Education; therefore, is not superior to the participants which reduced the likelihood that the participants would misrepresent themselves. The use of multiple data collection instruments ensured that the data generated from one data collecting instrument could be corroborated with the data generated from another.

Creswell (2014) adds that interviews generate data in a selected location rather than the natural setting and that not all people can fully articulate themselves which influences the information supplied. These disadvantages did not influence the current research as the semi-structured interviews were conducted in the participants' classrooms which were their natural settings related to the phenomena. Conducting the interviews in their classrooms and implementing a probing strategy during the semi-structured interviews ensured the participants engaged with the questions posed. It was noted that, while responding to one aspect of the interview, some participants included other aspects. This was taken as them feeling free and comfortable during the interview process. A contributing factor for this sense of freedom and comfortability of the participants could be attributed to the interviews taking place in their classrooms during a

break or non-teaching period. This setting encouraged the participants to be expressive and authentic in their responses generating insightful data prescribed for qualitative research.

3.6.3.3 Document analysis

In negotiating a date for the semi-structured interviews with each participant as mentioned in Section 3.6.3.2, the participants were informed that upon the conclusion of the semi-structured interview, they could submit their lesson plan as discussed in the information session.

- Dealing with the challenges of document analysis

Generating data from documents does have potential limitations which include that not all participants have the same articulation abilities; documents may not be for public access (protected); and the information could be hard-to-find places (Creswell, 2014). The design of the lesson plan template is an adaptation of the Kwa-Zulu Natal Department of Education lesson plan and is user-friendly. This familiarity and user-friendliness allowed all the participants to respond to generate data applicable to instructional strategies even if their articulation abilities were different. The issues of the documents being protected and in hard-to-find places were negated by the participants consenting to be part of the current research and providing lesson plans that had already been designed. According to Creswell (2014), some documents may not justify their assumptions as they might be unrelated. In selecting a lesson plan as a document, the researcher was cautious to select an applicable document.

3.6.4 Data Analysis

3.6.4.1 The process of data analysis

Qualitative data analysis involves the processes of classifying, examining and understanding the data (McMillan & Schumacher, 1993). According to Marshall and Rossman (1999), data analysis is "bringing order, structure and interpretation to the mass of collected data. It is the search for general statements about relationships among categories of data" (p. 150). Cohen et al. (2007) state that the analysis of qualitative data is the organising, accounting for and making sense of the data relative to how the participants understood and explained the phenomenon of the research. It involves observing patterns, themes, categories and regularities. Lastly, data analysis is viewed as the researcher establishing relationships between several emerging themes facilitated by describing and summarising the words obtained from the data collection instruments (Lacey & Luff, 2009). The definitions reveal that data analysis involves making

meaning of generated data by employing specific procedures that provide reasoning regarding participants' engagement with the phenomenon of the research.

Several methods namely grounded theory, discourse analysis, content analysis, grounded analysis and guided analysis can be used to analyse qualitative data (Miles & Huberman, 1994). Each of these methods communicates a distinctive viewpoint of analysing data. Considering the phenomenon, research questions, aims and theoretical framework employed, the current research adopted guided analysis as the method to analyse the data to generate findings. Guided analysis is in line with the description of qualitative data analysis involving understanding data by noting patterns, themes and categories (Cohen et al., 2011).

Often referred to as thematic analysis, guided analysis is used to analyse classifications and present themes from the data (Alhojailan, 2012). It involves modifying emerging themes and classifications by interacting with data (Khoza, 2013). It is suitable for research that aims to discover understanding using interpretations. Qualitative data analysis can be directed by inductive and deductive reasoning methods. Most social research studies combine both reasoning methods (Christiansen et al., 2010). In the case of inductive reasoning, the production of authentic data is the starting point. The researcher then recognises patterns and categories emerging from the data which is open-ended and expository.

Deductive reasoning is more theoretically grounded which differs from the open-ended nature of inductive reasoning (Christiansen et al., 2010). This suggests that deductive reasoning establishes classifications for arranging data informed by the applicable theory relevant to the topic being investigated. In this case, the theoretical framework and other concepts which underpin the current research were used to organise data into categories. For example, the dimensions in the RRCM (Holt et al., 2007) informed these categories. According to Gibbs (2007), qualitative data analysis is based on established beliefs and theories which the theoretical framework supplies. The use of both inductive and deductive reasoning to analyse data supports the rationale for the use of guided analysis adopted for the current research. An open-ended and theory-informed analysis provides for comprehensive findings from the analysis of the data.

3.6.4.2 The stages of the data analysis

Before discussing the analysis of the data from each data collection instrument, a description of the various stages involved with data analysis is necessary. Figure 3.4 illustrates the six stages of data analysis proposed by Braun and Clarke (2006).

Figure 3.4: The Six Stages of Data Analysis

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┌─────────────────────────────────────────────────────┐
│              ┌───────────────────┐                    │
│              │  Stage 1: Get     │                    │
│              │  Familiar         │                    │
│              └───────────────────┘                    │
│                       ↓                               │
│              ┌───────────────────┐                    │
│              │  Stage 2:         │                    │
│              │  Generate Codes   │                    │
│              └───────────────────┘                    │
│                       ↓                               │
│              ┌───────────────────┐                    │
│              │  Stage 3: Theme   │                    │
│              │  Search           │                    │
│              └───────────────────┘                    │
│                       ↓                               │
│              ┌───────────────────┐                    │
│              │  Stage 4: Theme   │                    │
│              │  Review           │                    │
│              └───────────────────┘                    │
│                       ↓                               │
│              ┌───────────────────┐                    │
│              │  Stage 5: Define  │                    │
│              │  Themes           │                    │
│              └───────────────────┘                    │
│                       ↓                               │
│              ┌───────────────────┐                    │
│              │  Stage 6: Present │                    │
│              │  and Discuss      │                    │
│              └───────────────────┘                    │
└─────────────────────────────────────────────────────┘
```
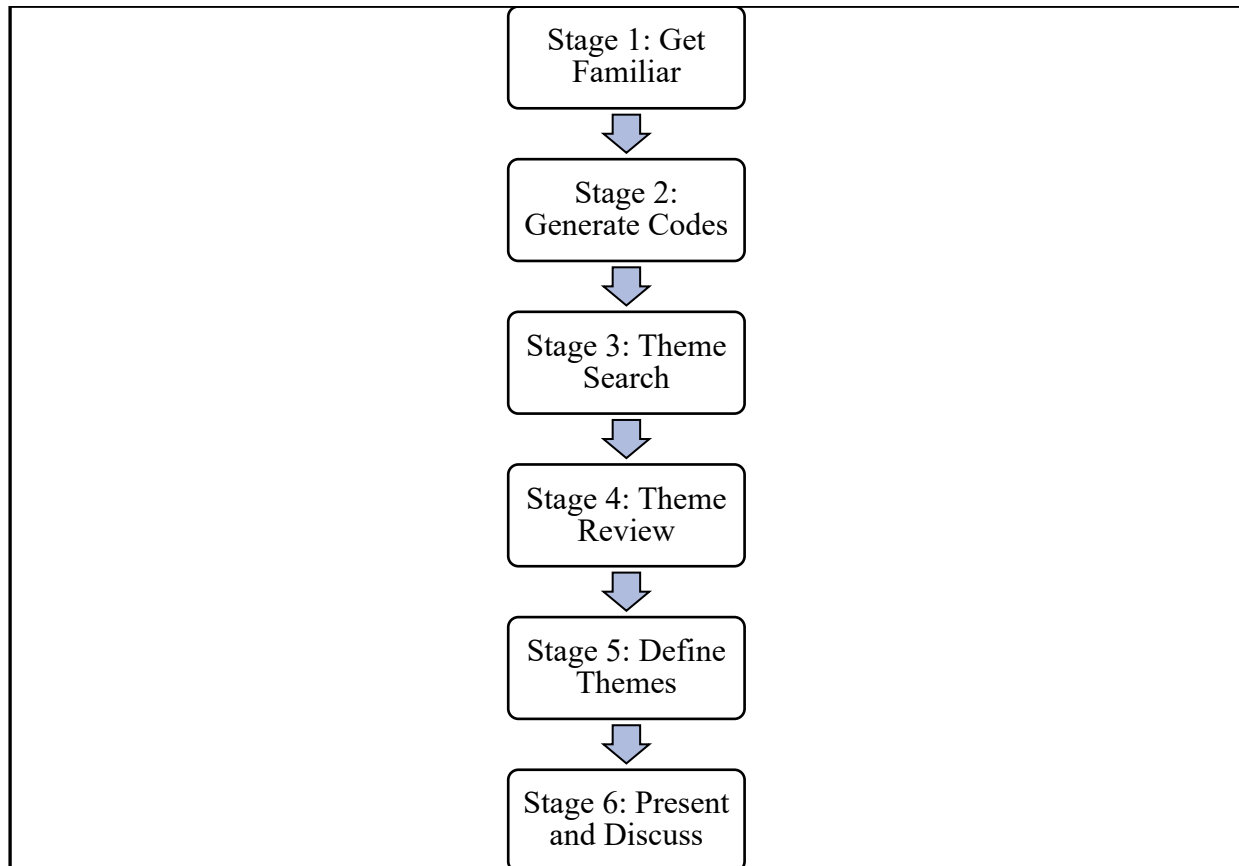
Source: (Adapted from Braun & Clarke, 2006)

According to Braun and Clarke (2006), the six stages depicted in Figure 3.4 are not static but rather fluid and should be aligned with the research questions and data. This suggests that employing guided analysis enables the researcher to be flexible in choosing ways to analyse and communicate the data. The first stage, according to Braun and Clarke (2006), is the researcher familiarising themselves with the data. This involves the researcher engrossing themselves in the data to connect with the content. This assists in overcoming possible inherent analytical interests or preconceptions. It involves reading the data repeatedly to identify patterns and trends that allow for coding and establishing themes. The researcher spent considerable time with the data to acquire a clear picture of possible patterns relating to the

research questions. This involved documenting thoughts, facilitated by well-kept and organised records.

Following the first stage is the identification of codes or categories. These categories identify features of the raw data and generally appear during the first stage of familiarisation. They are representative of the noteworthy ideas that are distinctive to the phenomenon of the research. Identifying the categories includes organising the ideas into groups or themes. After reading through the responses of the participants, the researcher started classifying ideas into specific categories that were informed by the research questions and the related questions found in the data collection instruments. According to Miles and Huberman (1994), this stage involves data reduction where conclusions and verifications are facilitated by streamlining and translating the data into categories that are used to identify the most important meaning. The third stage is searching for themes (Braun & Clarke, 2006). The identification of categories from the previous stage allows for them to be organised into potential themes. In this stage, consideration is given to the connection between the categories and themes and the separate levels of themes, such as main themes and sub-themes. In the data analysis of the current research and relating to this stage, once categories were identified the researcher organised them into themes.

The fourth stage of the data analysis process is the reviewing of the identified themes where there may be the realisation that some are not themes as there might not be sufficient data to constitute them as a theme. The reviewing of the themes may lead to their intersection. Complex themes might need to be simplified into sub-themes or developed into new themes. The fifth stage involves defining and naming the themes by identifying their core principles and redefining them to present for analysis. The individual themes should reveal a story that explains what it is while simultaneously complementing the other themes. Sub-themes may also develop from this activity.

The last stage requires the production of a report serving as the final analysis of all the developed themes. It describes the research communicating the merit and validity of the analysis. The analysis should be concise, coherent and a repetitive account of the data through the themes. Graphic examples or quotations from the data should be selected to encapsulate the core of the themes. Every effort was made to follow a logical sequence in presenting the themes while being cognisant that these themes intersect with each other. The presentation of

the analysis of the data of the current research covers the authentic and essential meaning of the data.

3.6.4.3 The implementation of the data analysis stages

Data was analysed broadly (inductively) by identifying emerging themes, patterns and categories of the various aspects concerned with the participants' instructional strategies leading to some general conclusions. Data was also analysed deductively, possibly adding to relevant findings related to participants' readiness for change informed by the aspects of the theoretical framework to establish categories for organising data applicable to the phenomenon.

Section 1 of the open-ended questionnaire explored the participants' biographical information, their exposure to instructional strategies and the 4IR. It was simple to document and state the individual experiences in terms of their teaching experience in Life Sciences, their qualifications and their exposure to instructional strategies and the 4IR. Part A of Section 2 explored the participants' understanding of education in the 4IR through their responses to statements on a Likert scale. The analysis of this Section involved identifying which responses of the participants contributed to the level of the participant's understanding of the skills and learning experiences applicable to the 4IR. Part B of Section 2 explored the instructional strategies the participants intended to adopt in the 4IR and required them to justify or support their choice. Identified instructional strategies and the participants' justifications were placed into categories. Section 3 consisted of open-ended questions on the participants' understandings of the 4IR, instructional strategies and their prior experiences with curriculum reform. Here, too, data were analysed by identifying themes and patterns using the applicable theory to suggest findings.

Data from the semi-structured interviews was analysed by listening to the audio recordings and making verbatim transcriptions. This involved replaying the audio recordings to ensure that the transcriptions were accurate which allowed for familiarisation with the data and assisted in identifying general inferences. The lesson plans were analysed using the lesson plan analysis schedule (Appendix J) to document the lesson plan information namely the participant, the lesson topic, the specific aims, the duration and the prior knowledge covered. A summary of the components of the lesson plan was also done including the teacher activities, the learner activities, the resources, the activities given, the enrichment, the homework and the teacher

reflection. The analysis also involved documenting if the lesson plan incorporated aspects of learning experiences applicable to the 4IR (WEF, 2020).

3.7 TRUSTWORTHINESS

According to Morse et al. (2002), securing rigour involves employing several verification methods during research to establish reliability and validity and hence its quality. According to Christiansen et al. (2010), reliability and validity are related to measurement where reliability is concerned with the degree to which a test or instrument can be replicated and yield identical outcomes. Validity relates to the researchers' instrument evaluating what it asserts to evaluate (Cohen et al., 2011). The concepts of reliability and validity do not apply to the current research as qualitative research like a case study aims to explain meanings or personal experiences and not to measure. These concepts are substituted by the concept of trustworthiness which consists of credibility, transferability, dependability and conformability (Guba & Lincoln, 1994).

3.7.1 Credibility

Credibility ensures belief in the findings and involves implementing measures to establish it which include prolonged engagement, triangulation and member checks (Lincoln & Guba, 1985). Prolonged engagement refers to the researcher spending sufficient time in the field to appreciate the social setting, and the phenomenon and foster relationships with participants. The prolonged engagement was secured by the researcher of the current research spending a substantial amount of time first, reviewing the literature to understand the phenomenon of it and second, with the participants while collecting the data. Having previously interacted professionally with the participants, the issue of developing relationships was secured. The semi-structured interviews were recorded and transcribed. Important information was not excluded as this transcribing entailed lengthy engagement with the data to produce credible findings based on sufficient evidence. Triangulation using multiple data collection instruments to produce a deeper understanding ensured credibility. According to Lincoln and Guba (1985), member checks are concerned with data being evaluated by the participants enabling them to verify and provide additional data. Interview transcripts were returned to the participants for their verification.

3.7.2 Transferability

According to Lincoln and Guba (1985), transferability refers to the applicability of the findings to other settings. Thick description is a method used to obtain transferability. This is done with sufficient detail provided in the description of the phenomenon where an assessment can be conducted in terms of the degree to which the findings are transferable to other settings. A thick description is supplied in Chapter 2 discussing the theory that underpins the current research and its research methodology discussed in this chapter. Providing a thick description also aided in the credibility as a thorough explanation ensures confidence in the findings.

3.7.3 Dependability

Dependability relates to the consistency and repeatability of the findings which is also secured by thick description (Lincoln & Guba, 1985). External audits involve the scrutiny of the research process and findings by another researcher and add to the dependability of the study. This is done to ascertain the exactness of findings based on the data. Frequent discussions with the supervisor of the current research were arranged to examine the findings. These discussions included the contesting of the methods and conclusions which promoted the accuracy.

Nowell et al. (2017) posit several actions a researcher can use to secure the trustworthiness of the data analysis process. These include prolonged engagement with the data**,** documenting thoughts about possible codes or themes, keeping records of all data field notes and transcripts**,** researcher triangulation**,** member checking and audit trails.

Prolonged engagement took place throughout the analysis of the data in the form of the researcher getting familiar with the data to suggest possible themes and later refinement. This refinement of themes occurred with the assistance of researcher triangulation which involved consulting the supervisor of the current research. Consulting also limited biases as the supervisor reviewed drafts of the analysis of data and made me aware of possible biases. Towards the end of the analysis of data member checks enabled the participants to verify the information they provided (Lincoln & Guba, 1985). The meticulous record-keeping of field notes and transcriptions of the semi-structured interviews provided a detailed and clear audit trail. This audit trail involved a description of the decisions taken and the justification of the use of the data collection instruments and the data they generated. These measures secured the trustworthiness of the analysis of the data process.

3.7.4 Conformability

Conformability is the degree of neutrality to which the findings of a study are generated by the participants and not by researcher bias. External audits strengthen conformability as the supervisor evaluates the findings for researcher bias (Lincoln & Guba, 1985). To further strengthen conformability, an audit trail was used (Nowell et al., 2017). This involves a transparent description of the research steps followed during the study from the first steps to the reporting of the findings of the study. This is evident by once again supplying a thick description and by explaining the researcher's role to the participants before the generation of data. The open-ended questionnaire being self-administered also prevented researcher bias. When participants responded to the open-ended questionnaire, there was no input from the researcher to influence them. Triangulation was implemented thereby corroborating data to avoid bias. Conformability was also secured by member checks (Lincoln & Guba, 1985). Participants were allowed to verify the accuracy of the verbatim transcripts from the semi-structured interviews (Ndlovu, 2012).

3.8 ETHICAL CONSIDERATIONS

According to Strydom (2005), essential to successful research is the awareness and implementation of ethical issues as research involves human beings. At the core of this is the researcher protecting the rights of the participants ensuring that no harm is experienced from their participation in the research. Wassenaar (2006) postulates that all research studies must adhere to certain ethical principles. McMillan and Schumacher (2010) add that ethics include certain aspects observed in the principles put forward by Wassenaar (2006). The discussion below indicates the role of the researcher in securing the ethics of the current research with the principles and aspects (McMillan & Schumacher, 2010; Wassenaar, 2006).

3.8.1 Accessing Participants

This stage was initiated by compiling a research proposal and submitted to the research proposal review committee. After receiving approval, the research proposal was then submitted to the University of South Africa's College of Education's ethics review committee to review the ethical aspects of the current research to obtain ethical clearance. Ethical clearance was duly granted with the issuing of an ethical clearance certificate (Appendix A) which allowed the researcher to conduct the current research. Obtaining ethical clearance allowed the researcher to seek permission in writing from the school principals of prospective participants

(Appendix B). This involved scheduling a meeting with the prospective schools' principals where the scope of the research was outlined (Cohen et al., 2011). Permission was duly granted by the principals to approach prospective participants (Appendix C).

3.8.2 Informed Consent

Babbie (2007) states that individuals participating in a study should be informed of the overall conditions of what is appropriate and inappropriate. Cohen et al. (2007) state that "informed consent is the procedure in which individuals choose whether to participate in an investigation after being informed of facts that would be likely to influence their decisions" (p. 52). Informed consent was sought from the prospective participants by asking them to read through an information sheet and signing an informed letter of consent (Appendices D and E). The letter outlined the purpose of the study, the right to voluntary participation and withdrawal from it (autonomy), the data collection instruments, the possible benefits of the study (beneficence), the right of participants to anonymity (pseudonyms are used) and confidentiality, the dissemination of the findings and the freedom to seek clarity on any part of the study.

As stated in the introduction of this Section, the principles suggested by Wassenaar (2006) are also discussed which encompass the ethical aspects (McMillan & Schumacher, 2010) included in the informed letter of consent. In terms of autonomy, Wassenaar (2006) explains it as respecting individual participants' rights, actions and thoughts. The researcher was mindful not to offend participants based on their responses given in the data collection instruments. Since participants were entitled to express open-ended responses, the researcher respected their viewpoints. In addition, participants have the option to remove themselves at any stage in the research process. Beneficence relates to a study benefitting other researchers or society at large (Christiansen et al., 2010). The current research would create awareness regarding the 4IR and teachers' teaching practices.

While participating in research there is the risk of an individual experiencing physical and emotional harm (Strydom, 2005). The avoidance of such relates to informing the participants about possible risks of the research and providing them with the option of withdrawal. This is in line with the principle of non-maleficence which means 'no harm' and is concerned with the research not causing any harm, intentional injury, or emotional offence (Wassenaar, 2006). The researcher ensured that the environment in which the semi-structured interviews took place was safe and that confidentiality was adhered to in terms of the participants' identities and

responses as a lack of understanding of the phenomenon might cause harm in their workplace. Christiansen et al. (2010) recognise the need to ensure the confidentiality of the information provided by participants and inform the participants of how the findings will be made known. Confidentiality was secured by the researcher being the only person who engaged with the data generated. In addition to this and to prevent other persons from accessing generated data, all data is in locked storage and electronic copies are password-protected. In terms of anonymity, pseudonyms are used for each participant to ensure that their identity is unknown.

3.9 CONCLUSION

This chapter presented in detail the research methodology guiding the current research to address the research questions. It explained and justified the selection of the aspects of the research methodology. These aspects included the research paradigm, approach and design. An account of the research methods was then provided which outlined the sampling, the data collection instruments, the data collection procedure and the analysis of data. The chapter concluded by explaining the measures employed to secure trustworthiness and the ethical considerations of the current research.

The next chapter presents the results, supported by evidence from the analysis of the data generated by the participants. The evidence of the results is presented with the use of verbatim quotations.

CHAPTER 4: DISCOVERING AND REVEALING THE JOURNEY'S ATTRACTIONS

"Qualitative research allows for richer, more insightful (and sometimes unexpected) results. This is often what is needed when we want to dive deeper into a research question."

Kerryn Warren

4.1 INTRODUCTION

The previous chapter reported on the research methodology applied in the current research providing a detailed account and justification for the data collection instruments used. The current chapter presents the results from the analysis of the data generated. It endeavours to present the data sequentially, exploring each research sub-question in detail. This is consistent with an effective case study report being linear, comparative, sequential, theory developing or sequenced processing (Yin, 2003). There are instances where there is a deviation from this sequential exploration where relevant data presents an opportunity to respond to another research sub-question. According to Baxter and Jack (2008), case study reporting is chiefly concerned with sequentially relating a story but there is no right or wrong way of doing it.

To further justify sequentially addressing each research sub-question is the analogy of an onion (Saunders et al., 2016). To expose the centre of an onion, each of its layers needs to be peeled back. The centre of the onion represents the main research question of the current research concerned with the development of a framework that can enhance in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies. Addressing each research sub-question sequentially represents the peeling back of each layer of the onion. It is this peeling back of each layer, represented by the results for that research sub-question facilitates the development of the framework.

To enhance the results, data from multiple data collection instruments is presented by triangulating the results, thus securing their credibility (Yin, 2003). Data is presented in tables comprised of verbatim quotations from the participants and, in some instances, findings are also presented in the table.

4.2 PARTICIPANTS' UNDERSTANDING OF 4IR-BASED INSTRUCTIONAL STRATEGIES

The first research sub-question is "What is in-service Life Sciences teachers' understanding of 4IR-based instructional strategies?" Results showed that the participants exhibit a range of proficiency in their understanding of 4IR-based instructional strategies. Table 4.1 identifies several aspects that inform this observation.

Table 4.1: The Aspects that Inform the Participants' Ranging Proficiency in their Understanding of 4IR-based instructional strategies

Finding	Aspects informing the finding
The participants exhibit a range of proficiency in their understanding of 4IR-based instructional strategies	The participants' understanding of the 4IR, comprised of: • Concerned with the use of technology • Influencing an individual's everyday life • Presenting challenges • The need for training • Requires new instructional strategies influencing their teaching practice • Non-exposure to the 4IR • Varying degrees of the current implementation of technology
	Varying understandings of the term "instructional strategies" (informing alignment of understandings to 4IR instructional strategies-research sub-question three)
	Varying identifications of both the skills to be developed in the 4IR and the characteristics of the learning experiences that will develop such skills (informing alignment of understandings to 4IR instructional strategies-research sub-question three)
	The participants intend to adopt diverse instructional strategies (informing alignment of understandings to 4IR instructional strategies-research sub-question three)

The current research found that participants demonstrated varied proficiency in understanding 4IR-based instructional strategies. This diversity is informed by multiple factors such as technology usage, daily life implications, challenges presented, the necessity for training and current technology implementation. Additionally, there were differing interpretations of "instructional strategies", intended skills development for 4IR, and planned adoption of diverse instructional approaches. Each of these factors is explored in detail in the following sub-sections.

4.2.1 Understandings of the 4IR

Data showed that the participants understand that the 4IR is concerned with the use of technology (Table 4.2). For example, participants used terms such as "technologically advanced world," "social media," and "robotics" to articulate their understanding. Kate focused on the integration of technology into institutions, while Emma emphasised a collaborative, technology-enabled approach in various domains. Peter saw 4IR as a confluence of technology, robotics and AI enhancing modern life. Mia succinctly pointed to the ubiquity of digital platforms, and Sophia envisioned a future dominated by computers and robots. Notably, the use of the terms shift and movement by Kate and Emma suggests that they envisaged a change concerned with the instructional strategies to be adopted in the 4IR based on the use of technology. The responses of Emma, Peter, Mia and Sophia indicate their understanding of the types of technologies that the 4IR uses. These include computers, robotics, AI, digital platforms and social media. Overall, the consensus points to a transformative impact of technology across sectors.

Table 4.2: Evidence of the Participants' Understanding of the 4IR is Concerned with Technology

Participant	Verbatim evidence from the open-ended questionnaire	Verbatim evidence from the semi-structured interview
Kate	*A shift to a more technological advanced world.*	*It's about bringing in technology into various institutions.*
Emma	*A movement towards the use of technology and social media. A more connected and*	

Participant	Verbatim evidence from the open-ended questionnaire	Verbatim evidence from the semi-structured interview
	collaborative approach to work, education and daily life.	
Peter	*About the advancement and innovative ways of modern daily lives through technology, robotics and artificial intelligence.*	*I think it's just talking about the innovation and the advancement of modern-day life.*
Mia	*Using technology/digital platforms in all aspects.*	
Sophia	*I understand that it will be digital mostly computer, robots, computerised.*	

It also emerged that the participants believed that technology influenced everyday life (Table 4.3). This is evident in the explanation of Amelia who identified a change in the way we live with the introduction of new technologies. This was corroborated by Kate who explained that the 4IR is about bringing technology into institutions, the workplace and the world which suggests that technology influences everyday life.

Table 4.3: Evidence that the Participants Believe that Technology Will Influence Everyday Life

Participant	Verbatim evidence from the open-ended questionnaire	Verbatim evidence from the semi-structured interview
Amelia	*A change in the way we live by the introduction of new technologies.*	
Mia	*Using technology/digital platforms in all aspects.*	
Olivia	*All spheres of human existence will involve the pervasive use of technology.*	

Participant	Verbatim evidence from the open-ended questionnaire	Verbatim evidence from the semi-structured interview
Kate		*It's about bringing in technology into various institutions, workplaces, into the world.*
Peter		*I think it's just talking about the innovation and the advancement of modern-day life.*

Data also showed that participants believe that new instructional strategies are required in the 4IR (Table 4.4). Here, evidence suggests that participants overwhelmingly agreed on the necessity of adopting new instructional strategies for education in the context of the 4IR. Charlotte emphasised the importance of incorporating technology to make educational content more relevant to real-world scenarios. Emma argued for a transition from traditional textbook-based approaches to technology-guided methods, emphasising the dynamic nature of teaching in the modern age. Sophia explicitly mentioned the need to integrate 4IR-relevant technology into lesson plans. Lastly, Kate contended that classroom strategies must evolve to adequately prepare students for the challenges and opportunities presented by the 4IR.

Table 4.4: Evidence that the Participants Believe that New instructional strategies are Required in the 4IR

Participant	Verbatim evidence from the open-ended questionnaire	Verbatim evidence from the semi-structured interview
Charlotte	*Using new innovative ways of imparting knowledge to keep up with rapid changes in the world. Change the methods currently used at present because methods more appealing to the learners will be an option.*	*The use of technology will make the content studied at school level more relevant to real-life situations. It will better prepare learners for jobs in the future as they will be equipped with the necessary skills required.*
Emma	*Teaching is not something that can remain stagnant. As we move to a more modern and*	*It's a move from a textbook-based work, learners working individually to more of a technology-based work. Using*

Participant	Verbatim evidence from the open-ended questionnaire	Verbatim evidence from the semi-structured interview
	technological life, education needs to reflect this.	*technology as a guide for them when querying or answering specific questions.*
Sophia	*I may need to integrate technology that promotes the fourth industrial revolution into my lesson plans.*	
Kate		*Strategies in the classroom need to change. So that we equip the learners with skills to face the fourth industrial revolution out there.*

The evidence presented in Tables 4.2, 4.3 and 4.4 determined the participants' understanding of the 4IR. In determining the participants' understandings of the 4IR, non-exposure to it was acknowledged. During the semi-structured interview, Amelia explained:

> *To tell you honestly, I had no idea about this until you had given me that first questionnaire and that's when I went and read about it. So, I'm not going to lie, I actually forgot what it means and what's it about.*

Data from the open-ended questionnaire corroborated Amelia's acknowledgement of not being aware of the 4IR before the current research commenced. All the participants indicated that the 4IR was not part of their professional development as it was not discussed when they attended departmental meetings or workshops. As shown in Table 4.5, participants shared the same sentiment concerning their non-exposure to the 4IR.

Table 4.5: Evidence of the Participants' Non-Exposure to the 4IR

Participant	Verbatim evidence from the open-ended questionnaire
Kate	*The focus is always on the present, preparing learners for the current/ upcoming examinations.*
Ava	*Never. I don't even think they are able to take on the task themselves like the many policies created. They make the policies but it is us the level one educators that create the engine and drive it.*

Participant	Verbatim evidence from the open-ended questionnaire
Mia	*There has not been a single workshop by the DOE to even begin this.*

Given the apparent lack of exposure to 4IR, participants pointed to challenges associated with the incorporation of technology (Table 4.6). In this regard, Charlotte emphasised the need for technology and facilities for both educators and learners. Sophia highlighted the infrastructural limitations, particularly the lack of computers. Kate pointed to community impoverishment and limited technology exposure among learners, except for cell phones. Amelia identified financial constraints in rural schools as a significant barrier to introducing technology, thus hampering progress towards the 4IR. The participants' perspectives were drawn from both open-ended questionnaires and semi-structured interviews, revealing multifaceted challenges across different contexts.

Table 4.6: Evidence of the Identification of Challenges by the Participants

Participant	Verbatim evidence from the open-ended questionnaire	Verbatim evidence from the semi-structured interview
Charlotte	*Provided the necessary technology and facilities are available to educators and learners.*	
Sophia	*In our country, the infrastructure is still not available. We still battling with computers in our school to type and paper.*	
Kate		*In terms of our community here, very impoverished, our learners haven't been exposed to technology as such besides the cell phone.*
Amelia		*Definitely, but then you know that the issue comes when we have poor schools in the rural areas that, you know, we can't afford to introduce technology in the classroom because of the lack of resources. So that kind of puts a hindrance to the 4IR.*

Noting the challenges faced when integrating 4IR technologies, and the lack of professional development initiatives, the participants generally agreed that there is a need for training to equip them with the necessary skills (Table 4.7). Specifically, participants expressed concerns regarding their preparedness to implement modern educational methods. Isabella emphasised that proper training was lacking, elaborating in the semi-structured interviews that teachers were not well-equipped for implementation. Ava suggested she might benefit from attending courses. Charlotte explicitly stated her lack of training in requisite methods. Sophia did not respond to the open-ended questionnaire but noted in her interview that, while proficient in computer use, she was unfamiliar with operating projectors. Emma showed enthusiasm for training opportunities, particularly in media and technology use. Overall, the participants called attention to the need for more comprehensive training.

Table 4.7: Evidence of the Participants' Call for Training

Participant	Verbatim evidence from the open-ended questionnaire	Verbatim evidence from semi-structured interviews
Isabella	*Proper training is still needed.*	*Training is needed, as teachers we are not well-equipped with how to implement it. So it will make education easier but to implement it will take time.*
Ava	*I need to perhaps attend some courses.*	
Charlotte	*I was not trained to use the methods required.*	
Sophia		*I need more because I don't know how to use a projector, but I do know how to use a computer.*
Emma		*I would jump at the opportunity to be trained in the use of media and technology.*

While they may not have formal professional development, the participants indicated that 4IR technologies had already influenced their teaching practice (Table 4.8). For example, Emma indicated that educational practices had already shifted towards digital means, as students predominantly sourced information from the internet rather than libraries. Similarly, Mia revealed a post-COVID transformation in her teaching methods, increasingly using social

media and virtual platforms like WhatsApp for lesson dissemination and individualised student engagement. Both highlighted an evolving landscape of digital integration in pedagogy.

Table 4.8: Evidence of Technology Already Influencing the Participants' Teaching Practice

Participant	Verbatim evidence from the semi-structured interview
Emma	*Oh, I think it already is. For us now if we give things like assignments, we are not expecting learners to get information from the library. Most of them will say to you. Miss, how do you reference this if I'm getting this from the Internet? So already it's being used in some forms.*
Mia	*Once COVID hit I became more interactive on social media with the learners. So, I'm actually now at a stage where I film some of my lessons and then I present it on WhatsApp. I do that quite often and I'm having more one-on-one conversations with them, but not physically it's now more virtual than ever.*

The revelation that 4IR technology is already influencing the participants' teaching practice was corroborated through document analysis which involved the analysis of the participants' lesson plans. Emma (Figure 4.1a) confirmed her use of 4IR technology by indicating the use of videos and an interactive smartboard, Kate (Figure 4.1b) and Ava (Figure 4.1c) added to this by indicating the use of the internet and a projector respectively. These resources imply the use of a computer as well.

Figure 4.1a: The Resources Used by Emma

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Figure 4.1b: The Resources Used by Kate

Teacher activities	Learner activities	Resources		Written task or activity
ACTIVITY 1 : INTRO • REVIEW CLASSIFICATION OF ANIMAL KINGDOM (QUESTION/ANSWER METHOD) • INTERPRETS A PHYLOGENETIC TREE TO SHOW PLACE OF FAMILY HOMINIDAE IN THE ANIMAL KINGDOM	• RESPOND TO QUESTIONS AND TAKE DOWN SUMMARY • LISTEN , TAKE NOTES AND DRAW A PHYLOGENETIC TREE	Chalkboard		WRITTEN IN LIFE SCIENCES BOOK .
		Charts		
		Posters		
		Magazines		
		Newspaper		
		Video – INTERNET	✓	
		DVD		
		Worksheet	✓	
		Learners Other (list below)		
		TEXTBOOKS	✓	

Figure 4.1c: The Resources Used by Ava

Teacher activities	Learner activities	Resources		Written task or activity
1) Show learners light microscope. Explain how these instruments enabled people to see cell structures which lead to cell theory. 2) Illustrate a diagram of a plant cell and explain the role function of each organelle. 3) Illustrate a diagram of an animal cell and explain the role function. 4) Show learners video Plant vs animal cells https://www.patreon.com/neutralacademy 5) Show learners images of what plant and animal cells look like under microscope.	–In groups – learners must assemble a paper puzzle of both plant and animal cell. Each organelle is labelled.	Chalkboard		–Study & Master: Module 7 Units 1 & 2 pg
		Charts		
		Posters		
		Magazines		
		Newspaper		
		Video	×	
		DVD		
		Worksheet	×	
		Learners Other (list below)	×	
		Whiteboard	×	
		Projector	×	
		Enrichment: https://www.youtube.com/watch?v=24YMQ9GvLss		

What emerged strongly from the data is that 4IR technology already influences some of the participants' teaching practices. While some of the participants' lesson plans showed evidence of incorporation of 4IR technology, this was not the case with other participants. For example, Charlotte (Figure 4.2a) indicated the use of the chalkboard and a worksheet. Sophia (Figure 4.2b) added to these when indicating the use of a textbook and pictures. Olivia (Figure 4.2c) added to a textbook by indicating that she used the annual teaching plan and previous examination papers. These resources are used in a traditional lesson, one that has a teacher-centred approach.

Figure 4.2a: The Resources Used by Charlotte

Prior Knowledge:	REQUIREMENTS + PRODUCTS OF PHOTOSYNTHESIS STRUCTURE + FUNCTION OF CHLOROPLAST			
Teacher activities	**Learner activities**	**Resources**		**Written task or activity**
– REVIEW THE STRUCTURE OF THE CHLOROPLAST – SITE OF LIGHT PHASE (GRANA) AND DARK PHASE (STROMA) – BRIEFLY OUTLINE THE LIGHT AND DARK PHASES	– CONTRIBUTE TO THE LESSON BY ASKING + ANSWERING QUESTIONS – COMPLETE QUES BASED ON THE LESSON.	Chalkboard	✓	QUESTIONS FROM PAST EXAM PAPERS
		Charts		
		Posters		
		Magazines		
		Newspaper		
		Video		
		DVD		
		Worksheet	✓	
		Learners		
		Other (list below)		
		Enrichment: ADDITIONAL WORKSHEETS		
		Homework: COMPLETION OF WORKSHEET		

Figure 4.2b: The Resources Used by Sophia

Teacher activities	Learner activities	Resources		Written task or activity
WILL USE THE TEXT BOOK PAGE 13 OF EXAM FEVER AS NOTE – TEACHER WILL USE THE BOOK TO EXPLAIN WHAT MICRO-ORGANISMS ARE, DIFFERENT TYPES – DISEASES THEY CAUSE – How They are SPREAD – BRIEF SUMMARY OF THE NOTES WILL BE WRITTEN ON THE BOARD Teacher will Give Homework. Prepare and Write Chalkboard summary Prepare Worksheet for Activity	LEARNERS WILL LOOK AT THEIR NOTES, HIGHLIGHT AND UNDERLINE IMPORTANT INFORMATION They will listen – WRITE DOWN NOTES TAKE WORKSHEET Activity	Chalkboard	✓	Notes Classwork Homework
		Charts		
		Posters		
		Magazines		
		Newspaper		
		Video		
		DVD		
		Worksheet	✓	
		Learners	✓	
		Other (list below)		
		Text book	✓	
		Pictures	✓	
		Enrichment: NOTE		
		Homework: WILL BE GIVEN		

Figure 4.2c: The Resources Used by Olivia

PRIOR-KNOWLEDGE/ BACKGROUND KNOWLEDGE
• Respiratory systems • Cellular respiration
RESOURCES
Textbooks, ATP, Previous question papers
ERRORS/MISCONCEPTIONS/PROBLEM AREAS
• Aerobic and anaerobic • Gaseous exchange and breathing

The evidence presented in Table 4.8 and Figures 4.1a, b, c – 4.2a, b, c shows that technology has influenced the participants' teaching practices to varying degrees.

4.2.2 Reflection on Understandings of the 4IR

The current research focused on participants' understanding of the 4IR and its impact on instructional strategies in educational settings. Key findings revealed that participants associated 4IR with transformative technological advancements like robotics, AI and digital platforms. A consensus emerged on the necessity to adapt instructional strategies for education in a 4IR context. Participants identified a need for technology-integrated lesson plans and a move from traditional textbook-based approaches to technology-guided methods. Despite this recognition, participants indicated a lack of formal professional development on 4IR, with no departmental meetings or workshops discussing it. They identified multiple challenges to 4IR adoption, including infrastructural limitations and financial constraints, particularly in rural schools. Interestingly, the data showed that 4IR technologies had already started influencing some teaching practices. Participants had begun using digital resources like videos, smartboards and the internet. However, participants unanimously called for more comprehensive training to equip them with the necessary skills for successful 4IR integration in educational settings. Overall, the current research emphasises the transformative impact of 4IR technology in education but notes the systemic and infrastructural challenges that need to be addressed.

4.2.3 Understanding of "Instructional Strategies"

Participants' understanding of the term "instructional strategies" in the context of 4IR was explored as a broader analysis of their understanding of 4IR and its influence on pedagogy (Table 4.9). This was particularly important given the increased use of 4IR technologies in teaching as reported by some of the participants. Results revealed varying degrees of the participants' understanding of the term "instructional strategies". For example, Kate, Emma and Sophia suggested that instructional strategies are used in teaching to convey or deliver information. Emma supplied examples of instructional strategies which suggest a deeper understanding. In her response, Mia demonstrated uncertainty which could be attributed to a lack of understanding.

Table 4.9: Evidence of the Participants' Understanding of Instructional Strategies

Participant	Verbatim evidence from the open-ended questionnaire
Kate	*Techniques that are used for teaching and learning.*
Emma	*These are strategies used by educators to convey information. It could include traditional teacher-to-learner instruction, collaboration/peer teaching or even learner-centred/guided teaching.*
Sophia	*Methods or ways used to deliver information.*
Mia	*Unsure, perhaps ways of developing tools which allows learners to complete tasks and then reflect on them.*

The participants' varying understandings of the term "instructional strategies" contributing to their understanding of 4IR-based instructional strategies were used to address the first part of the third research sub-question which is "To what extent are in-service Life Sciences teachers' understandings of 4IR-based instructional strategies … in line with 4IR-based instructional strategies?" The participants' explanations in Table 4.9 identified an uncertainty, a basic and a deep understanding of the term. This range of understanding contributes to varying degrees of alignment in their understanding of 4IR-based instructional strategies and points to their ranging proficiency in their understanding.

4.2.4 Content Relevant to the Development of the Skills Required in the 4IR

New curricula and teaching approaches are required for education to deliver the needs of society that are related to the development of skills required by learners to cope and thrive in it. An awareness of the skills required contributes to or informs the participants' understanding of 4IR-based instructional strategies. This awareness influences the decisions of teachers concerned with the instructional strategies to select (Table 4.10). Participants stressed the importance of a global awareness focusing on sustainability and global community involvement. They also highlighted the need for innovation skills such as complex problem-solving and analytical thinking. Digital literacy, encompassing programming and responsible technology use, was deemed essential. Lastly, interpersonal and emotional intelligence skills, including empathy and leadership, were emphasised as crucial for effective communication and management.

Table 4.10: The Content the Participants' Views Relevant for the Development of the Skills Required in the 4IR

Participant	Content relevant to the skills that need to be developed in the 4IR identified in the open-ended questionnaire	Verbatim evidence from the semi-structured interview
Kate, Emma, Charlotte, Sophia, Amelia, Mia, Peter, Ava, Olivia	Emphasis on building awareness concerned with the wider world, sustainability and playing an active role in the global community	
Kate, Emma, Charlotte, Amelia, Mia, Peter, Ava, Isabella, Olivia	Develops skills necessary for innovation, including complex problem-solving, analytical thinking, creativity and system analysis	*Be creative, make good decisions, be to able think critically and be able to solve problems.*
Kate, Emma, Charlotte, Sophia, Amelia, Peter, Ava, Isabella, Olivia	Grounded in creating digital skills, including programming, digital responsibility and the use of technology	*It is being familiar with some sort of technology because you cannot move forward into using technology in working with one another if you are not exposed to any form of technology.* *Need to be computer literate.*
Kate, Emma, Charlotte, Amelia, Mia, Ava	Concentrates on interpersonal emotional intelligence, including empathy, cooperation, negotiation, leadership and social awareness	*I think communication is key because you must be able to speak to somebody effectively where they would understand you. Must be able to manage people.*

As shown in Table 4.10, the skills identified by the participants varied. To a large degree with explanations, the participants identified skills related to technology and innovation. To a lesser degree, the participants identified skills concerned with interpersonal skills which are related to collaboration and communication.

The participants' choice of necessary skills for the 4IR influenced their diverse understanding of 4IR-based instructional strategies, which was used to address the first part of the third

research sub-question which is "To what extent are in-service Life Sciences teachers' understandings of 4IR-based instructional strategies … in line with 4IR-based instructional strategies?" Table 4.10 presented evidence of the participants' identifying different skills to be developed in the 4IR. The relevant skills were not unanimously identified by the participants. These differences indicate a range of proficiency in their understanding of 4IR-based instructional strategies and therefore reveal varying degrees of alignment in their understanding.

4.2.5 Characteristics of Learning Experiences Selected

As indicated in Table 4.1, another aspect that emerged concerning the participants' understanding of 4IR related to skills to be developed in the 4IR and the characteristics of the learning experiences that would develop such skills. Having identified the skills (Section 4.2.4), the next task was to identify the characteristics of the learning experiences in the 4IR that facilitate the development of the skills.

As shown in Table 4.11 the participants identified various characteristics of the learning experiences in the 4IR. For example, Statement 1 (Table 4.11) posits that learning is standardised in its delivery in the 4IR. This is not the case in the 4IR and therefore to disagree with this statement is the appropriate response. Kate, Emma, Charlotte and Amelia responded appropriately. Mia, Ava, Isabella and Olivia agreed with Statement 1 and their responses are therefore inappropriate. Sophia and Peter were unsure. This indicates the variation in the participants' identification of the characteristics of learning experiences in the 4IR as the participants exhibited this attribute when responding to the other statements in the table. Where some of their responses are appropriate while others are not.

Table 4.11: The Participants' Appropriate Responses to Statements Related to the Characteristics of Learning Experiences in the 4IR

Statement number	Characteristics of the learning experiences in the 4IR	Participants who supplied the appropriate response to the statement
1.	Learning is standardised in its delivery	Kate, Emma, Charlotte, Amelia

Statement number	Characteristics of the learning experiences in the 4IR	Participants who supplied the appropriate response to the statement
2.	Learning caters to the diverse individual needs of each learner	Kate, Charlotte, Sophia, Isabella, Olivia
3.	Everyone has access to learning and is therefore inclusive	Charlotte, Sophia, Olivia
4.	Learning is process-based	Amelia, Ava
5.	Learning necessitates peer collaboration and more closely reflecting the future of work	Emma, Charlotte, Amelia, Peter, Ava, Isabella, Olivia
6.	Learning is a system where learning and skilling decrease over one's lifespan	Kate, Emma, Charlotte, Sophia, Amelia, Mia, Olivia
7	Learning involves project and problem-based content delivery	Emma, Charlotte, Sophia, Amelia, Mia, Ava, Isabella, Olivia
8.	Learning is limited to those with access to school buildings	Kate, Emma, Charlotte, Sophia, Amelia, Mia, Isabella, Olivia
9.	Learning is adaptable enough to empower each learner to improve at their own pace	Kate, Charlotte, Amelia, Mia, Ava, Isabella, Olivia
10.	Learning involves everyone constantly expanding on existing skills and securing new ones based on their individual needs	Kate, Emma, Charlotte, Amelia, Mia, Ava, Isabella, Olivia

The range of the characteristics of the learning experiences in the 4IR identified by the participants presented in Table 4.11 signifies their grasp of 4IR-based instructional strategies. These characteristics are also used to gauge how well the participants' understanding aligns with 4IR-based instructional strategies. This addresses the first part of the third research sub-question which is "To what extent are in-service Life Sciences teachers' understandings of 4IR-based instructional strategies … in line with 4IR-based instructional strategies?" Responses to the statements that were appropriate indicated alignment while inappropriate

responses indicated non-alignment. This alignment and non-alignment enhanced the participants' varying degrees of alignment in their understanding of 4IR-based instructional strategies and therefore points to their varied proficiency in their understanding.

4.2.6 Reflection on the Research Sub-Question/s Addressed

Sections 4.2.2–4.2.5 contribute to the participants' range of proficiency in their understanding of 4IR-based instructional strategies indicated. In reflecting on Section 4.2.1, Section 4.2.2 summarised that teachers understand the 4IR's transformative influence on their teaching practice due to 4IR technology. Other aspects of their understanding of the 4IR included the need for professional development on the 4IR and systemic and infrastructural challenges that need to be addressed. Through these revelations, the participants are deemed to have a proficient understanding of the 4IR which supports the proficiency in the finding of their understanding of 4IR-based instructional strategies. Sections 4.2.3–4.2.5 contributed to the range of proficiency as the participants showed varying understandings of the term "instructional strategies", selected varied skills required in the 4IR and selected varied characteristics of the learning experiences to develop these skills in the 4IR respectively. In some cases, the characteristics selected were appropriate while others were not.

Sections 4.2.3–4.2.5 supported the ranging proficiency of the participants and, in part, addressed the third research sub-question which explored the extent to which the participants' understandings of 4IR-based instructional strategies are aligned with 4IR-based instructional strategies. The participants ranging proficiency in their understandings due to Sections 4.2.3–4.2.5 demonstrate varying alignments in terms of their understandings with 4IR-based instructional strategies, making each participant unique in this regard.

4.3 INSTRUCTIONAL STRATEGIES PARTICIPANTS INTEND TO ADOPT IN THE 4IR

The second research question is "What instructional strategies do in-service Life Sciences teachers intend to adopt in the 4IR?" It emerged that the participants intend to adopt direct instruction, indirect instruction, interactive instruction, experiential learning and independent study. It was also found that participants have a propensity for direct instruction. Table 4.12 presents evidence of the diverse instructional strategies the participants intend to adopt in the 4IR.

Table 4.12: The Diverse Instructional Strategies the Participants Intend to Adopt in the 4IR

Participant	Type of instructional strategy
Kate, Emma, Charlotte, Sophia, Amelia, Mia, Peter, Ava, Isabella, Olivia	Direct Instruction
Kate, Emma, Sophia, Amelia, Mia, Peter, Ava, Isabella, Olivia	Indirect Instruction
Kate, Emma, Sophia, Amelia, Mia, Peter, Ava, Olivia	Interactive Instruction
Kate, Emma, Charlotte, Sophia, Amelia, Mia, Ava, Olivia	Experiential Learning
Kate, Emma, Charlotte, Sophia, Amelia, Mia, Ava, Olivia	Independent Study

Direct instruction is a highly structured, teacher-centred approach primarily aimed at knowledge transmission from the instructor to the student. It usually employs lecture-based teaching, in which the teacher delivers factual information, explicitly outlines objectives and often follows a prescribed curriculum. Assessment is usually quantitative, employing standardised tests to evaluate student performance. Indirect instruction is a more student-centred approach, where learners actively engage with the material through problem-solving, case studies or projects. Unlike direct instruction, the instructor acts as a facilitator rather than a transmitter of knowledge. The primary aim is not just the absorption of facts but the cultivation of skills such as critical thinking and problem-solving. Interactive instruction involves reciprocal engagement between instructors and students as well as among students themselves. This approach often employs discussion, peer teaching and group activities. The aim is to foster a deeper understanding of the subject matter, critical thinking skills and a sense of community among learners. Experiential learning involves learning through hands-on experiences, observation and interaction with the real-world environment. It focuses on the cycle of learning that includes experience, reflection, conceptualisation and experimentation. It is particularly useful for skills-based and attitude-focused educational outcomes. Independent study is an SDL process wherein students are provided with the autonomy to explore subjects of their interest. The instructor's role is minimal, often relegated to that of an advisor. Students are expected to identify learning objectives, conduct research and evaluate their performance autonomously.

The selection of diverse and different instructional strategies enhances the finding that the participants' understanding of 4IR-based instructional strategies ranges in proficiency. These diverse instructional strategies demonstrated both teacher-centred and learner-centred approaches to teaching. A teacher-centred approach was evident in the selection of direct instruction. Evidence of a learner-centred approach was evident in the selection of indirect instruction, interactive instruction, experiential learning and independent study.

The fact that both teacher-centred and learner-centred approaches to teaching were used to establish the extent of the participants' proficiency in their understanding of 4IR-based instructional strategies enhanced their varying degrees of alignment in their understanding of 4IR-based instructional strategies. The selection and reliance on direct instruction detracts from their understandings and speaks to the non-alignment while the selection of indirect instruction, interactive instruction, experiential learning and independent study speaks to their alignment.

The selection of instructional strategies they intend to adopt which demonstrate teacher-centred and learner-centred approaches which include diverse and different instructional strategies addresses the second part of the third research sub-question which is "To what extent are in-service Life Sciences teachers' … intended instructional strategies in line with 4IR-based instructional strategies?" In terms of non-alignment, the participants' proclivity towards direct instruction supports a teacher-centred approach and conflicts with a learner-centred one. Intending to use diverse instructional strategies aligned with a learner-centred approach establishes alignment with 4IR-based instructional strategies. The non-alignment and alignment of their intended instructional strategies speak to the varied alignment of their intended instructional strategies to 4IR-based instructional strategies. Participants were probed further regarding the instructional strategies selected. Results in this regard are presented in Sections 4.3.1 – 4.3.5.

4.3.1 Direct Instruction

Table 4.13 presents the method of direct instruction preferred by the participants, the number of participants and the reason it was selected. As shown in the table, participants selected various methods of direct instruction and provided reasons for their choices. The lecture method was chosen by two participants, with Charlotte emphasising its necessity for explaining certain content. Explicit teaching was preferred by four participants, including Kate and Mia, who cited its indispensability for weaker learners. Drill-and-practice were selected by two

participants for consolidation purposes. The compare-and-contrast method was chosen by seven participants, with reasons focusing on skill development and concept consolidation. Demonstrations had the highest preference, selected by 10 participants for their visual and hands-on learning benefits. Finally, guided and shared learning was chosen by six participants, with Kate stressing the need to instil valuable skills in learners.

Table 4.13: The Methods of Direct Instruction Selected by the Participants and the Reasons for their Selection

Method of direct instruction	Number of participants who selected the method	Participant	Reason for selecting the method of direct instruction
Lecture Method	2	Charlotte	*This strategy will always have a place in education as some content needs to be explained for understanding purposes.*
Explicit Teaching	4	Kate	*Some topics require explicit teaching.*
		Mia	*I firmly believe that explicit teaching cannot be replaced as weaker learners need this.*
Drill and Practice	2	Olivia	*For consolidation.*
Compare and Contrast	7	Kate	*Learners need to develop these skills.*
		Olivia	*Concept building and consolidation.*
Demonstrations	10	Kate	*Hands-on experience to learning.*
		Charlotte	*Learners remember and understand more if the content is visual.*

Method of direct instruction	Number of participants who selected the method	Participant	Reason for selecting the method of direct instruction
		Mia	*When children are able to observe demonstrations, they will comprehend more.*
		Peter	*Learning through visualisation or using sight is very effective.*
		Olivia	*Practical work with learners.*
Guided and Shared Learning (Reading, Listening, Viewing, Thinking)	6	Kate	*These valuable skills need to be instilled in learners.*

The selection of demonstrations was corroborated by Peter in the semi-structured interview with the following response:

> *Okay, the first one could be adding more demonstrations to your lessons. Demonstrations could be a way to advance our lessons in the classroom.*

The analysis of data revealed further that the frequency of selecting methods within direct instruction was greater than those methods of the other instructional strategies that frame the current research (Table 4.12). This further suggests that the participants value and rely on direct instruction evident in a response by Kate when asked about what skills she thought were required for the 4IR. In identifying technological skills assisting in teaching, Kate in the semi-structured interview added that:

> *Having said that, it still doesn't take away the good old-fashioned actual experiments hands-on with the apparatus.*

Her response which includes the phrase 'good old-fashioned' implies direct instruction. The response corroborates the participants' justification for selecting other methods of direct instruction in Table 4.13 as always having a place in education and being necessary for weaker learners. This perception that direct instruction always has a place in education suggests that the participants currently relied on a teacher-centred approach facilitated by direct instruction in their teaching.

The participants' reliance on direct instruction that includes traditional teaching methods was corroborated by evidence from their lesson plans. The lesson plans identified that indeed their current practice relies on direct instruction. For example, Figures 4.2a, b and c provided evidence of the resources used by the participants showing that some participants were not infusing 4IR technology in their teaching practice. This evidence shows their reliance on direct instruction. These resources, namely, the chalkboard, textbooks, worksheets, charts, departmental revision documents, annual teaching plans and previous examination question papers are aligned with traditional methods of teaching that exhibit a teacher-centred approach. Figures 4.2a, b and c also include the teacher activities. The verbs used to cover content, namely, explain and outline are also aligned with traditional methods of teaching. Further evidence of the use of verbs that are aligned with direct instruction is provided in Figures 4.3a and b.

Figure 4.3a: The Verbs Used by Olivia


```
METHODOLOGY
LESSON 1
•    Define the following processes:
     ✓  cellular respiration
     ✓  breathing
     ✓  gas exchange
•    Differentiate between the following processes:
     ✓  cellular respiration
     ✓  breathing
     ✓  gas exchange
•    Explain the need for oxygen in the body and the n
```

Figure 4.3b: The Verbs Used by Mia


```
METHODOLOGY
LESSON 1
Introduction
•   Explain types of nucleic acids
•   Revise structure of cell emphasizing on nucleus, cytoplasm and ribosome
•   Explain DNA location (Nuclear DNA and Mitochondrial DNA)
```

A more nuanced analysis of the lesson plan supporting the identification of the reliance on direct instruction is that in Figures 4.1a, b, c – 4.2 a and b there is more text written for teacher activities compared to the text written for learner activities. Regarding learner activities, the participants indicated that the learners would listen, ask and answer questions. The evidence presented confirms that the participants currently employ a teacher-centred approach facilitated by traditional teaching methods associated with direct instruction.

Continuing with the presentation of data that substantiates the findings related to the instructional strategies the participants intend to adopt in the 4IR, it emerged that even though the participants rely on direct instruction they are open to adopting learner-centred instructional strategies (Table 4.14). Emma's responses emphasised the need for learning to be learner-centred by adapting the teaching to the ways learners learn. Charlotte linked learning to societal technological norms.

Table 4.14: Evidence of the Participants' Openness to Adopt Learner-Centred Instructional Strategies

Participant	Evidence of the openness to more learner-centred instructional strategies
Emma	*Teaching in the traditional sense would not hold /keep learners' attention. We must adapt our teaching methods to the ways in which learners grasp/learn best.*
Charlotte	*The present practices are boring for learners and they find it difficult to focus for an extended period of time. They have been born into a society where technology plays an important role in their lives.*

Evidence of the participants' openness to adopt learner-centred instructional strategies provided in Table 4.14 contrasts with their current teaching practice that exhibits a reliance on teacher-centred instructional strategies. This openness is corroborated by Sections 4.3.2 – 4.3.5.

4.3.2 Indirect Instruction

Table 4.15 presents the methods of indirect instruction selected by the participants, and the reasons for their selection. As shown in the table, participants selected various methods of indirect instruction and provided reasons for their choices. The problem-solving method was chosen by Charlotte who highlighted that many skills can be developed through this method. In selecting case studies, Peter cited that it promoted curiosity. The inquiry method was

selected with Olivia simply linking it to experimentation. The reason supplied by Kate for selecting reflective discussion was that listening to others develops social skills. Finally, Olivia selected both concept formation and concept mapping, citing that the former is related to Life Sciences and placed importance on the latter in terms of showing relationships.

Table 4.15: The Methods of Indirect Instruction Selected by the Participants and the Reasons for their Selection

Method of indirect instruction	Number of participants who selected the method	Participant	Reason for selecting the method of indirect instruction
Problem-Solving	6	Mia	*Many skills can be learnt through problem-solving.*
Case Studies	5	Peter	*This strategy encourages curiosity and higher-order thinking. This can help learners to do research.*
Inquiry	4	Olivia	*Experimentation*
Reflective Discussion	6	Mia	*Listening to others helps learners compare ideas, there is always room for reflection. This also assists with social skills.*
Concept Formation	4	Olivia	*Life Science involves concept formation.*
Concept Mapping	2	Olivia	*Important skill for learners to show relationships between concepts.*

The selection of methods and reasons provided in Table 4.15 indicate the participants' varied and proficient understanding of 4IR-based instructional strategies. This difference in understanding is evident in that a different number of participants and therefore different participants selected a particular method. Their proficiency is recognised in the identification

of the multiple methods within indirect instruction which implies the participants' openness to a more learner-centred approach and corroborates findings from Section 4.3.1.

4.3.3 Interactive Instruction

Table 4.16 presents the method of interactive instruction selected by the participants, the number of participants and, where supplied, the reason it was selected. No reason was supplied for some choices. In these cases, the participant who selected the method is stated. The brainstorming method was chosen where Olivia felt it was good to produce ideas. Mia believed that the peer learning method through laboratory activities created opportunities for learning and selecting laboratory groups as a method, citing that it develops social skills. Olivia's reason for selecting the problem-solving method was that it brought about an improvement in creative thinking. The structured controversy method was chosen with Peter highlighting that it can facilitate the sharing of knowledge. Finally, in selecting the interview method, Mia stated that it allows for the opportunity for the understanding of concepts.

Table 4.16: The Methods of Interactive Instruction Selected by the Participants and the Reasons for their Selection

Method of interactive instruction	Number of participants who selected the method	Participant	Reason for selecting the method of interactive instruction
Debates	2	Emma, Ava	
Role-playing	1	Ava	
Panels	1	Emma	
Brainstorming	4	Olivia	*Good for creating ideas.*
Peer Partner Learning	4	Mia	*Usually through lab work and problem-solving creates many learning opportunities.*

Method of interactive instruction	Number of participants who selected the method	Participant	Reason for selecting the method of interactive instruction
Discussion	6	Kate, Emma, Sophia, Amelia, Mia, Olivia	
Laboratory Groups	7	Mia	*Social skills, as well as cognitive processing, is developed.*
Cooperative Learning	3	Olivia	*Working in groups. Team building skills.*
Problem-Solving	6	Mia	*Some learners experience learning barriers if the teaching is content-based, problem-solving seems more relatable.*
		Olivia	*Improve learners' creative thinking skills.*
Structured Controversy	2	Peter	*This can set a common ground on a topic. While arguing learners could learn from each other.*
Tutorial Groups	2	Emma, Ava	
Interviewing	1	Mia	*Learners have to develop material which creates platforms for understanding concepts/phenomena being investigated.*
Conferencing	1	Sophia	

The selection of methods in Table 4.16 with reasons indicates the participants' varied understandings of 4IR-based instructional strategies. This range of understanding is again

evident in different participants selected a particular method. Their proficiency in their understanding is evident in the identification of the multiple methods within interactive instruction and that these methods are conducive to a higher degree of learner involvement. This implies the participants' openness to a more learner-centred approach corroborating findings from Section 4.3.1. The selection of interactive instruction which encompasses several methods was corroborated by Peter in the semi-structured interview with the following response:

When it comes to how learners can interact with each other. You can do group work.

4.3.4 Experiential Learning

Table 4.17 presents the method of experiential learning selected by the participants, the number of participants and, where supplied, the reason it was selected. In certain of the selected methods, no reason for it was supplied. In these cases, the participant who selected the method is stated. As shown in the table, participants selected various methods of experiential learning and some provided reasons for their choices. The field trips method was chosen, with Charlotte highlighting that Life Sciences lends itself to field trips in terms of the scientific method. This was also the reason supplied by Olivia for the selection of the method of conducting experiments. The simulations method was also chosen by Charlotte who cited that it fostered better understanding. Mia, in selecting the games method supplied an example of the DNA card game and stated that it too developed understanding. Finally, field observation was chosen by Olivia who simply stated that they allow for observations which is also in line with the scientific method.

Table 4.17: The Methods of Experiential Learning Selected by the Participants and the Reasons for their Selection

Method of experiential learning	Number of participants who selected the method	Participant	Reason for selecting the method of experiential learning
Field Trips	6	Charlotte	*Life Sciences lends itself to field trips where learners can collect data which can be analysed to*

Method of experiential learning	Number of participants who selected the method	Participant	Reason for selecting the method of experiential learning
			come to suitable conclusions.
Conducting Experiments	7	Olivia	*Subjects lends itself to conduct experiments.*
Simulations	3	Charlotte	*Can be used for better understanding of certain concepts.*
Games	8	Mia	*DNA and protein synthesis is understood by developing games using amino acids and DNA cards.*
Storytelling	1	Sophia	
Field Observations	2	Olivia	*Learners study environment and make observations.*
Synectics (Creative thinking to problem-solving)	3	Emma, Sophia, Ava	

The selection of methods in Table 4.17 with reasons further indicates the participants' varied and proficient understanding of 4IR-based instructional strategies. Their proficiency is further based on the participants identifying multiple methods within experiential learning and that these methods are conducive to a higher degree of learner involvement which implies the participants' openness to a more learner-centred approach corroborating findings from Section 4.3.1.

The implication of experiential learning's value was conveyed by Mia who indicated that:

This is the most influential form of interactive teaching as learners are able to understand through doing.

The selection of experiential learning in terms of simulations was corroborated by Kate in the semi-structured interview with the following response:

Depends on the topic. If I'm doing a lesson, for example, on the Heart. I would use a simulation because that's where the learners can actually see the blood flowing from chamber to chamber into the artery, veins etc. The movement of blood flow, so I would rely quite heavily on the simulations.

Kate highlighted the use of a combination of instructional strategies approach as she indicated a method which is concerned with experiential learning in the form of simulation and a method which is concerned with independent study (Section 4.3.5) in the form of computer-assisted learning.

4.3.5 Independent Study

Table 4.18 presents the methods of independent study selected by the participants, the number of participants and, where supplied, the reason it was selected. No reasons were supplied for some of the selections. In these cases, the participant who selected the method is stated. The reports method was chosen with Peter citing that this promoted research which fostered independent thinking. The learning activity packages method was also selected where Olivia stated that they are used for revision purposes. Homework was selected by Charlotte who explained that it was used to reinforce and test understanding. Finally, Olivia, in selecting research projects, stated that it was a subject requirement.

Table 4.18: The Methods of Independent Study Selected by the Participants and the Reasons for their Selection

Method of independent study	Number of participants who selected the method	Participant	Reason for selecting the method of independent study
Computer-Assisted Instruction	4	Emma, Sophia, Ava, Olivia	
Reports	5	Peter	*Reports encourage research and independent views.*
Learning Activity Packages	5	Olivia	*Required, used for revision and consolidation.*
Correspondence Lessons	2	Emma, Sophia	
Learning Contracts	1	Emma	
Homework	6	Charlotte:	*Needed to reinforce the content learnt and test their understanding.*
Research Projects	6	Olivia	*Subject requirement.*
Assigned Questions	6	Kate, Emma, Sophia, Amelia, Ava, Olivia	

The selection of methods in Table 4.18 with reasons further contributes to the participants' ranging and proficient understanding of 4IR-based instructional strategies. Their proficiency in terms of their understanding is further based on their identification of multiple methods within independent study and in their statements that these methods are again conducive to a higher degree of learner involvement which implies the participants' openness to a more learner-centred approach, supporting findings from Section 4.3.1.

The selection of independent study was corroborated by Kate in the semi-structured interview with the following response:

The way learners start doing their projects needs to change. For example, they should be at this stage be typing out the assignments and projects and get to a stage whereby they are able to e-mail it to their teacher or if they are absent via an online system so that teaching can continue even when the teachers away or the learners away.

4.3.6 Reflection on the Research Sub-Question/s Addressed

This Section responded to the second research sub-question which sought to determine the instructional strategies, that in-service Life Sciences teachers intend to adopt in the 4IR. It was found that the participants intend to use diverse instructional strategies to varying degrees in the 4IR contributing to their ranging proficiency in their understanding of 4IR-based instructional strategies (research sub-question one). It was also found that the participants valued and relied on a teacher-centred approach to learning in the 4IR through the selection with explanations of methods related to direct instruction. This enhanced the finding that the understandings of the participants exhibit different degrees of alignment in their understandings of 4IR-based instructional strategies (research sub-question three). This reasoning can be extrapolated to the other aspect of the third research question which explores the extent to which their intended instructional strategies are aligned with 4IR-based instructional strategies.

4.4 PARTICIPANTS' READINESS TO ADOPT 4IR-BASED INSTRUCTIONAL STRATEGIES

The introduction of this chapter explained that findings related to the first three research sub-questions in Sections 4.2 and 4.3 contribute to findings to the fourth research sub-question which is "What is the readiness of in-service Life Sciences teachers to adopt 4IR-based instructional strategies?" It emerged from the data relevant to the theoretical framework that the participants exhibited varying degrees of readiness to adopt 4IR-based instructional strategies. These varying degrees of readiness display aspects which are deemed to both support and stifle their adoption.

4.4.1 Revised Readiness for Change Model

Table 4.19 indicates that the participants have consensus and non-consensus on certain dimensions of the RRCM (Holt et al., 2007). There was consensus on the dimensions of appropriateness, management support and personal valence. In terms of appropriateness, the participants viewed the influence of the 4IR as necessary. In terms of management support, the participants identified the need for it and a lack of confidence in receiving it. The last dimension where there was consensus was personal valence where the participants believed that they would benefit from the influence of the 4IR. These benefits included personal growth, saving time and satisfaction from the learners achieving. The non-consensus was on the dimension of self-efficacy where the participants indicated having different abilities to perform the activity. The consensus and non-consensus in this dimension inform the finding that the participants exhibit varying degrees of readiness to adopt 4IR-based instructional strategies.

Table 4.19: Findings and Evidence Related to the RRCM

Dimension	Finding	Participant	Verbatim evidence from the semi-structured interview
Appropriateness	The participants view the influence of the 4IR on their teaching practice as necessary.	Kate	*You cannot be using teaching methods, teaching styles that belonged to a previous era because you are not going to produce a generation that's going to cope with the 4th Industrial Revolution.*
		Emma	*We must adapt our teaching methods to the ways in which learners grasp/learn best.*
Management Support	The participants value the support but do not think it will be provided.	Sophia	*I need the support from the supervisors, the principal and also from the Department of Education as well.*
		Kate	*To be honest. Nobody I've got to drive the process myself. I've got to see what I lack and find the means and ways in terms of resources to bring about this change.*

Self-Efficacy	The participants have different abilities to perform the activity.	Kate	*I don't believe that I know or I'm au fait with everything that's out there in terms of technology.*
		Emma	*I've been using technology in my classroom and lessons for a period of time already.*
Personal Valence	The participants identified benefits from the influence of the 4IR.	Kate	*I will benefit as a person. In terms of learning new stuff and it's not only me that's going to benefit, but I'll also impart it.*
		Mia	*Any type of knowledge, any type of change is always a good thing, especially when technology is concerned. Growth can never be a negative thing.*
		Emma	*I'm talking about the time spent preparing lessons, the time can be shortened.*
		Mia	*As teachers, we also get our rewards through the learners doing well so with this type of new way performance will increase and we'll feel more satisfied. They improve, I get personal satisfaction from it.*

The dimensions of appropriateness and personal valence where there is consensus among the participants are deemed to support the adoption of 4IR-based instructional strategies. For example, individuals who believe that the change is necessary are more likely to adopt the change. The consensus in management support and non-consensus in self-efficacy in terms of some of the participants believing they are not ready to implement the change is deemed to stifle the adoption of 4IR-based instructional strategies.

4.4.2 Attitudes Towards Adopting 4IR-based Instructional Strategies

Participants' attitudes towards adopting 4IR-based instructional strategies also emerged from the data, albeit briefly. Table 4.20 presents evidence related to the participants' general attitudes towards change. It indicates that, generally, the participants had a positive attitude towards change although initially there was a certain amount of hesitance, fear and resistance. Kate explained that when it comes to change, she has a positive attitude towards it. This was corroborated by Emma who explained that most change is good. Hesitance, fear and resistance were acknowledged in the responses of Charlotte and Emma. Charlotte added that her acceptance of the change came with clarity of the change.

Table 4.20: The Participants' General Attitudes Towards Change

Participant	Verbatim evidence from the semi-structured interview
Kate	*Overall, positively. I do go through the motions in my mind of how am I going to carry out this change and I look for ways and means of carrying out the change to make it work.*
Charlotte	*Hesitant initially, fear of the unknown. Acceptance when clarity is obtained.*
Emma	*I think there's always resistance when it comes to change. It's difficult. It takes an adjustment period but I think most change is good.*

A more nuanced analysis of the participants' attitudes towards the adoption of 4IR-based instructional strategies was explored through the array of forces shaping an attitude that either supports or resists change. Table 4.21 presents the forces that shape an attitude, the findings for each force and the evidence provided by the participants to support these findings.

Table 4.21: Findings and Evidence Related to the Forces that Shape an Attitude

The force that shapes an attitude	Findings	Verbatim evidence from the semi-structured interview
Job Outcome Forces	The participants identified that they would acquire job satisfaction. The participants have differences in their readiness to implement the	*Any type of knowledge, any type of change is always a good thing, especially when technology is concerned.*

The force that shapes an attitude	Findings	Verbatim evidence from the semi-structured interview
	change concerning their abilities due to concerns about workload.	*Growth can never be a negative thing.* *I don't believe that I know or I'm au fait with everything that's out there in terms of technology.*
Trust in the Principal and Colleagues	The participants have a lack of trust in the principal.	*To be honest. Nobody I've got to drive the process myself. I've got to see what I lack and find the means and ways in terms of resources to bring about this change.*
Role of Process Factors	The participants do not think participative management and the distribution of knowledge will be forthcoming due to the lack of trust in the principal.	*To be honest. Nobody I've got to drive the process myself. I've got to see what I lack and find the means and ways in terms of resources to bring about this change.*

The findings for each force shaping an attitude in Table 4.21 indicate that the participants have both positivity and negativity in their attitudes toward adopting 4IR-based instructional strategies. A force contributing positively to their attitudes, the participants believed that when learners achieved the required outcomes as a result of the adoption of 4IR-based instructional strategies, they would achieve job satisfaction. A force contributing negatively to their attitudes was mistrust of their principal. The positivity and negativity toward the adoption of 4IR-based instructional strategies led to varying degrees of readiness to adopt 4IR-based instructional strategies. Furthermore, the positivity and negativity in the participants' attitudes were deemed to support and stifle the adoption of 4IR-based instructional strategies respectively.

4.4.3 The Unified Theory of Acceptance and Use of Technology

Participants' intention to use 4IR technologies was also explored using the UTAUT (Venkatesh et al., 2003). The findings for each factor and the evidence provided by the participants to support them are presented in Table 4.22. It emerged with performance expectancy that the participants believed that 4IR technology would improve their performance. In terms of effort expectancy, the participants were at various levels of the skills required to infuse 4IR technology into the classroom. In acknowledging their level of skills, the participants corroborated the finding of the call for training identified in Section 4.2.1. When adopting a new system or behaviour, the participants were not generally influenced by others but rather by the value of the new system which relates to the factor of social influence. Lastly, concerning the facilitating conditions factor, the participants operated in different infrastructure environments. The various schools in which they taught differed in the resources available to facilitate the use of technology.

Table 4.22: Findings and Evidence Related to the UTAUT

Factor	Finding	Participant	Verbatim evidence from the semi-structured interview
Performance Expectancy	The participants believe technology would improve their performance.	Mia	*Look technology will improve the learners, number one. I'll have greater access to them.*
		Peter	*It is much easier to have access to that type of knowledge, so when making an example, you don't have to draw. You can just like use what we have as computers and iPads.*
Effort Expectancy	The participants exhibit various skill levels in terms of infusing technology into the classroom.	Kate	*I would use the word, limited skills. I'm learning on the job. Right, with the limited skills and knowledge that I have and that is the reason for wanting to be upskilled with professional development.*
		Emma	*Yes, I do. I use it.*
		Sophia	*Little bit. I need more training.*

		Mia	*I don't. I'm not at that level. Smart boards and stuff like that but not all of us have been workshopped.*
Social Influence	Influenced by the value of the new system or action.	Sophia	*I am influenced by how that particular thing will change my life. If it benefits me, then I'll do it.*
		Kate	*I actually would adopt it as well if it's going to improve the teaching and learning situation.*
Facilitating Conditions	Different degrees of infrastructure.	Amelia	*No, not at this school.*
		Mia	*So, we on the ground. We at grassroots level we are moving in that direction.*
		Kate	*This school has the means but it's a lack of thought.*

The difference in the responses in terms of the factors that contributed to the participants' varying degrees of readiness to adopt 4IR-based instructional strategies informs the classification of aspects which are deemed to support or stifle the adoption of 4IR-based instructional strategies. For instance, participants who believe that 4IR technologies enhance their performance, possess the skills to integrate these technologies into the classroom, appreciate the new system, and have valuable resources in terms of 4IR technology are aspects considered to be supportive of the adoption of 4IR-based instructional strategies. Aspects which are deemed to stifle the adoption of 4IR-based instructional strategies include the participants not having the skills to infuse 4IR technology into the classroom, seeing no value in the new system, not being motivated by others and functioning in an under-resourced school.

4.4.4 Reflection on the Research Sub-Question Addressed

This Section revealed that the participants exhibit varying degrees of readiness to adopt 4IR-based instructional strategies. These varying degrees of readiness display aspects which both support and hinder their adoption. This is informed by differences in the responses of the participants in terms of the dimensions of the RRCM (Holt et al., 2007), the forces that shape an attitude and the factors of the UTAUT (Venkatesh et al., 2003).

4.5 CONCLUSION

This chapter presented the findings which responded to the research sub-questions and therefore achieved the aims of developing a framework to enhance the readiness to adopt 4IR-based instructional strategies. Section 4.2 addressed the first research sub-question where it emerged that the participants exhibited a range of proficiency in their understanding of 4IR-based instructional strategies. This understanding was informed by their proficient understanding of the 4IR, their varying understandings of the term "instructional strategies", their varying identifications of both the skills to be developed by learners in the 4IR and the characteristics of the learning experiences that would develop such skills and their intention to adopt diverse instructional strategies (sub-question three, Section 4.3). Therefore, this finding achieves the aim relevant to the first research sub-question of the current research which was to determine in-service Life Sciences teachers' understanding of 4IR-based instructional strategies.

Section 4.3 addressed the second research sub-question where it emerged that the participants intended to adopt diverse instructional strategies which included direct instruction, indirect instruction, interactive instruction, experiential learning and independent study. It was found that the participants relied on and valued direct instruction which typifies a teacher-centred approach. However, they were open to instructional strategies which allowed for a more learner-centred approach. This finding achieved the aim relevant to the second research sub-question of the current research, which was to determine what instructional strategies in-service Life Sciences teachers intend to adopt in the 4IR.

The findings of the first and second research sub-questions addressed the third research sub-question (Sections 4.2 and 4.3). The participants exhibiting a range of proficiency in their understanding of 4IR-based instructional strategies and their intention to adopt diverse instructional strategies informed the finding that there is both alignment and non-alignment to 4IR-based instructional strategies. This finding achieved the aim relevant to the third research sub-question of the current research which assesses the extent to which in-service Life Sciences teachers' understandings and intended use of instructional strategies were aligned with 4IR-based instructional strategies.

Finally, Section 4.4 addressed the fourth research sub-question where it emerged that the participants exhibited varying degrees of readiness to adopt 4IR-based instructional strategies

which consist of aspects that support and stifle their adoption. Contributing to this finding were the findings of the first three research sub-questions related to the theory that frames the readiness to change in the current research which included the RRCM, the participants' attitudes towards the adoption of 4IR-based instructional strategies and the UTAUT (Holt et al., 2007; Kondakci et al., 2017; Venkatesh et al., 2003). This finding achieves the aim relevant to the fourth research sub-question of the current research which was to determine and explore the readiness of in-service Life Sciences teachers to adopt 4IR-based instructional strategies. This readiness is used to develop a framework to enhance in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies.

The next chapter chapter discusses the findings presented in this chapter. This discussion is supported with relevant literature.

CHAPTER 5: EXPLORING THE JOURNEY'S ATTRACTIONS

"The aim of argument, or of discussion, should not be victory, but progress."

Joseph Joubert

5.1 INTRODUCTION

The central argument of the current research is that there is an urgency to enhance teacher readiness to adopt 4IR-based instructional strategies in Life Science education, to ensure relevance and competitiveness with international trends. Such adoption should also enhance learner performance through improved content understanding fostered by quality teaching, learning and assessment. However, as discussed in Chapter 1, to identify strategies to enhance teacher readiness, it was imperative to first address the key aims of the current research, namely, to determine in-service Life Sciences teachers' understandings of 4IR-based instructional strategies; determine what instructional strategies in-service Life Sciences teachers intended to adopt in the 4IR; to assess to what extent in-service Life Sciences teachers' understandings and intended practice of instructional strategies are in line with 4IR-based instructional strategies; and to determine and explore the readiness of in-service Life Sciences teachers to adopt 4IR-based instructional strategies. The preceding chapter presented the results that emerged from the analysis of the data generated in response to these aims. The current chapter discusses these results in relation to the findings which may corroborate or contradict literature as well as those that are novel. The discussion of the findings involves applying the theories that underpin the study to validate or invalidate them.

5.2 EXPLORING FINDINGS

As argued in Chapters 1 and 2, there is a dearth of research regarding South African teachers' understanding of 4IR-based instructional strategies. The current research has addressed this dearth by finding that teachers may exhibit a range of proficiency in their understanding of 4IR-based instructional strategies. This understanding is informed by their understanding of the 4IR, their understanding of "instructional strategies", their selection of the skills required in the 4IR, the characteristics of the learning experiences that will develop such skills and the instructional strategies they intend to adopt in the 4IR. The aspects informing their understanding of 4IR-based instructional strategies could also affect teacher readiness to adopt them in Life Sciences education.

5.2.1 Technology

Notably, teachers were found to understand that the 4IR is concerned with the use of technology. While 4IR is fundamentally technology-driven (Schwab, 2016), it must be highlighted that generally, all four industrial revolutions were driven by technological advancements which sought to enhance human civilisation. For instance, the 1IR was characterised by the mechanisation of textile production and the advent of steam power (Pomeranz, 2000). The 2IR was notable for mass production and electrical engineering (Chandler, 1990). The 3IR incorporated automated manufacturing and information technology. These revolutions, much like the 4IR, were technologically driven but had far-reaching implications beyond technology itself, impacting socioeconomic and cultural elements of society (Castells, 2011). Therefore, in the educational context, the understanding of 4IR should not be limited to technology; it should also encompass the implications for workforce requirements, skill development and pedagogical change. Teachers must be cognizant that the 4IR necessitates a shift from traditional rote learning towards skills like critical thinking, creativity and digital literacy.

Related to the 4IR being concerned with the use of technology the current research found that the participating teachers identified 4IR technologies including computers, robotics, AI, digital platforms and social media. These technologies are consistent with the 4IR technologies identified in the literature (Schwab, 2016). Koopman (2022) argued that teachers generally have a simplistic understanding of the 4IR in terms of its technologies because they cannot identify 4IR technologies. The view of the participating teachers that the 4IR is concerned with technology coupled with the ability to identify 4IR technologies contributes to a proficient understanding of the 4IR.

The current research also found a potential association between knowledge of 4IR technologies and their influence on everyday life. For example, the participating teachers indicated that the use of 4IR technologies will likely influence an individual's everyday life. While further research is required to explore this association, this finding corroborates research which has shown that the uptake of 4IR technologies could impact everyday life (Marwala, 2020; Moloi & Marwala, 2020; Schulze, 2019; Singaram & Mayer, 2022). Therefore, this view of the participating teachers also contributes to their proficient understanding of the 4IR as education is part of a learner's everyday life. This influence requires new instructional strategies to keep pace with the change (Menon & Castrillon, 2019; Webber-Youngman, 2017). The finding of a

proficient understanding of the 4IR suggests that teachers may be better prepared to integrate 4IR technologies as instructional technologies given their understanding that the 4IR requires their involvement.

The possible better preparedness of teachers to integrate 4IR technologies is due to the correlation existing between a teacher's understanding of a concept and their teaching practice. A good understanding of a concept manifests in its confident implementation. Using other concepts in Life Sciences to illustrate this point, teachers' understandings of the NOS influence their teaching practice (Singh, 1998). Naidoo (2010) found that teachers' understanding of IKS informed the different approaches implemented in their teaching practices. Considering these studies, the current researcher asserts that the participating teachers' proficient understanding of the 4IR is encouraging as it indicates their readiness to change as they will be confident to explore and navigate the adoption of 4IR-based instructional strategies. Therefore, this understanding may support the adoption of 4IR-based instructional strategies.

The proficient understanding of the 4IR can be further explored with it influencing an attitude. According to de Souza Barros and Elia (1998), a good understanding of a concept develops a positive attitude towards it. This suggests that through the participating teachers' proficient understanding of the 4IR, they may have positive attitudes towards the 4IR that support their readiness to adopt 4IR-based instructional strategies. This positive attitude towards change should be nurtured and developed to successfully implement the change.

5.2.2 Perceived Impact of 4IR Technologies on Teaching Practice

Findings related to the influence and impact of 4IR extend to teaching practice. In this regard, the current research found that the participating teachers believed that 4IR will influence their teaching practice, including a transition from traditional instructional strategies to ones which include collaborative learning. This transition can be conceptualised as "pedagogical-technological transformation", which is the intersectional changes occurring in the realms of teaching methodologies and technological advancements, targeting improvements in educational effectiveness and efficiency. This transformation is a multidimensional process that encapsulates both the integration of technology into pedagogical practices and the re-evaluation or redesign of pedagogical strategies considering emerging technologies. Often driven by advances such as AI, adaptive learning platforms and data analytics, this transformation aims to enhance learning outcomes, engagement and the overall educational

experience for both teachers and learners. The pedagogical-technological transformation seeks to synergise these elements to create a more effective, efficient and equitable educational environment. Research in this domain often explores how best to implement these changes, measure their impact, and ensure they are aligned with broader educational goals such as inclusivity and accessibility (Niess & Gillow-Wiles, 2017; Zhang, 2021). In practical terms, the transformation may manifest in several ways: flipped classrooms, problem-based learning enabled by digital simulations, personalised learning pathways supported by Big Data, or the use of virtual/augmented reality for experiential learning, to name a few.

However, this pedagogical-technological transformation requires teachers to change or incorporate teaching methods into their teaching practice that promote and reflect the 4IR. This is consistent with Webber-Youngman (2017), who asserts that the influence of the 4IR requires academic institutions to think differently about their teaching and learning approaches. Menon and Castrillon (2019) add that for education to deliver on the needs of society in the 4IR requires new teaching approaches. New teaching approaches suggest teachers think differently about the instructional strategies they adopt in the 4IR. This enhances the finding that the participating teachers have a proficient understanding of the 4IR.

Nababan et al. (2020) add and agree with Schwab (2016) that the 4IR is driven by technology and that education in the 4IR is characterised by using digital technology where learning can take place constantly without space and time limitations, suggesting the influence of technology on teaching practice. This affirms the participating teachers' suggestions of a move from traditional instructional strategies and demonstrates their proficient understanding of the 4IR. What is of concern is that in the South African context, teachers in rural schools are still using traditional teaching methods which contributes to a lack of readiness for basic education for the 4IR (Moloi & Mhlanga, 2021).

Interestingly, regarding the influence of technological advancements on teaching practice, the current research found that the participating teachers believed that it is necessary. This was revealed when engaging with the key dimension of appropriateness in the RRCM (Holt et al., 2007) which serves as a pertinent framework for evaluating teachers' readiness to adopt 4IR-based instructional strategies and 4IR technologies. The collective belief that the adoption of 4IR technologies is timely and necessary aligns with Cockburn's (2005) assertion that successful change is facilitated when it is willingly embraced. This willingness to embrace it can be viewed as a positive aspect of an attitude towards the change that supports the readiness

to adopt 4IR-based instructional strategies which is in line with the participating teachers' general positive attitude toward change established when exploring their attitudes.

This belief that the influence of the 4IR is necessary may be the participating teachers ascribing a benefit to it. This benefit was revealed when exploring the key dimension of personal valence, the job outcome force which includes job satisfaction and the factor of performance expectancy. These were explored in the RRCM (Holt et al., 2007), the forces that shape attitudes (Kondakci et al., 2017) and the UTAUT (Venkatesh et al., 2003) respectively. These also form part of the theoretical framework of this current research. Contributions from these three sources on this revelation serve to corroborate it. The individual's perception of benefits from the change resonates with Holt et al.'s (2007) argument that change is readily accepted when personal advantages are evident, contrasting with resistance when benefits are lacking (Dent & Goldberg, 1999). Benefits include personal growth, saving time and satisfaction from the learners achieving. In terms of securing job satisfaction, the participating teachers associated this with learner achievement. This is an aspect of their positivity in their attitude towards their readiness to adopt 4IR-based instructional strategies and is deemed to support it.

In terms of performance expectancy, the participating teachers' belief that technology would improve their performance resonates with Dwivedi et al.'s (2017) assertion that an individual is more likely to adopt a new behaviour when there is a perceived improved job performance and is, therefore, useful. According to Koopman (2022), teachers have a reluctance to use technology in their lessons if they view it as having no benefit to them or their learners. The belief that the influence of the 4IR through technological advancements on teaching practices is necessary due to the benefits contributing to positivity towards supporting the adoption of 4IR-based instructional strategies. This speaks to the readiness of the participating teachers to adopt them.

5.2.3 Lack of Resources Affecting the Influence of the 4IR

While the current research corroborates the literature concerning the potential impact of 4IR technologies on teaching practices, it was also found that this impact could be influenced by the availability of resources. This acknowledgement of the lack of resources affecting the influence of 4IR contributes to the proficiency in the participating teachers' understanding of their 4IR-based instructional strategies as their recognition of it is consistent with reports in the literature.

This lack of resources, especially in developing countries could limit the adoption of 4IR technologies in education (Kayembe & Nel, 2019; Moloi & Mhlanga, 2021). The current research found that this lack of resources was identified by the participating teachers when exploring the facilitating conditions of the UTAUT (Venkatesh et al., 2003). Facilitating conditions relates to the availability of the infrastructure that includes the technology teachers need to plan and deliver lessons effectively with consideration given to the skills required by learners in the 4IR (Dwivedi et al., 2017). Notably, the participating teachers operate in different infrastructure environments where the various schools in which they teach differ in the availability of resources to facilitate the use of technology. These schools have the resources, limited resources or no resources. According to Koopman (2022), a lack of availability of resources results in a reluctance of teachers to use technology in their classrooms. The schools that have the resources support the adoption of 4IR-based instructional strategies. Teachers who operate in a resource-limited school exhibit both supporting and hindering attitudes to adopt 4IR-based instructional strategies. Teachers in schools that have no resources could completely stifle the adoption of 4IR-based instructional strategies. This difference in the availability of resources leads to the assertion that varying readiness exists which displays aspects that may support or stifle the adoption of 4IR-based instructional strategies.

It was also found that the lack of resources is linked to the socioeconomic status of the community which the learners come from which includes the school they attend. This is in line with the participating teachers operating in different infrastructure environments discussed in the previous paragraph. The association between the socioeconomic status of the school and the adoption of 4IR technologies could hamper the development of twenty-first-century skills related to 4IR. As reported in the literature, lack of internet access, an insufficient number of computers and outdated software packages harm the adoption of 4IR technologies, and the development of twenty-first-century skills (Ghavifekr & Rosdy, 2015; Ojo & Adu, 2018; Van Rooy, 2012).

The lack of resources being dependent on the socioeconomic status of the community and school can be further explored concerning the ranking system used to categorise schools in South Africa. This system is the quintile system discussed in Section 3.6.1. The participating teacher who identified the lack of resources being dependent on the community taught in a Quintile 4 school which is a well-resourced school in terms of the categorisation criteria. It is,

therefore, noteworthy that even well-resourced schools feel ill-prepared in terms of resources and infrastructure for 4IR technologies. This view is not well reported in the literature and requires further investigation. The current researcher posits that the quintile system may not be suitable for classifying schools in terms of 4IR. Therefore, further research is required to determine the suitability of this system in the 4IR context.

It follows that the lack of resources could hinder the implementation of the curriculum that includes 4IR-based instructional strategies. This is a well-documented phenomenon in the South African context where the implementation of the CAPS curriculum faced several challenges due to the lack of resources (Maharajh et al., 2016). The current researcher argues that if curriculum implementation is limited by the availability of basic infrastructure, the need for 4IR technologies could pose a serious threat to education in South Africa and her competitiveness globally. This could be more pronounced in rural schools which have a poor basic infrastructure and a lack of basic resources such as water, sanitation and electricity (Du Plessis & Mestry, 2019). The current researcher contends, therefore, that the lack of resources could have a significant negative impact on the education system in South Africa.

5.2.4 A Need for Teacher Development Initiatives

Another factor that contributed to the participating teachers' proficient understanding of the 4IR in terms of the implications of it on their teaching practice was their call for training. This is associated with the key dimension of self-efficacy of the RRCM (Holt et al., 2007) which presents a nuanced challenge that contributes to a ranging proficiency in their understanding of 4IR-based instructional strategies. Self-efficacy is an individual's belief in their ability to perform a given activity which relates to their skill level. While some participating teachers expressed confidence in their ability to adapt to 4IR technologies, echoing Bandura's (1997) notion that self-efficacy drives engagement in tasks perceived as within one's skill set, others expressed reluctance. The difference in abilities in the participating teachers in this current research illustrates differences in their confidence in their skill set and therefore a varied understanding of 4IR-based instructional strategies at this point. Individuals who believe in their ability to adapt to 4IR-based instructional strategies demonstrate proficiency while those who do not illustrate a lack of proficiency. Therefore, a range of proficiency exists as the skills levels are unique to participating teachers.

Corroborating the participating teachers at various skill levels required to infuse technology into their teaching practice was the exploration of the effort expectancy factor of the UTAUT (Venkatesh et al., 2003) where effort expectancy is the ease with which an individual can use the system which relates to the skill set of said individual. The participating teachers who had some skills are in a better position to embrace the change due to a positive attitude towards it as successful change must be embraced (Cockburn, 2005). While those who believed they did not have the skills might not embrace it. According to Koopman (2022), teachers are reluctant to use technology in their teaching practice when they believe that using technology would require a lot of effort. Teachers who do not have the skills might consider that it would require a lot of effort to acquire the skills to use technology effectively and therefore be reluctant to do so. This hesitancy to adopt new methods could inhibit not just the implementation of innovative strategies but also have downstream effects on learner development in the 4IR context. The different skill levels of the participating teachers resulting in confidence or lack thereof can be viewed as either supporting or stifling the adoption of 4IR-based instructional strategies.

The participating teachers' lack of confidence in their abilities was a negative aspect of their attitudes, stifling the adoption of 4IR technologies. 4IR-based instructional strategies were, therefore, explored through the forces shaping attitudes (Kondakci et al., 2017). In terms of the job outcome force of workload which involves whether an individual believes they can complete their activities in the allocated time, most of the participating teachers believed that they were not ready to implement the change. According to Koopman (2022), individuals will avoid activities that they perceive to be beyond their skill set.

Linked to the different levels in the participating teachers' confidence in their skills to adopt 4IR-based instructional strategies were the varying degrees of technology implemented in their current teaching practice which justifies the call for training. Some of the participating teachers explained that technology to some degree had already influenced their teaching practice in the form of their teaching methods. The teaching methods currently used in these participating teachers' teaching practices included the use of mobile technologies and social media applications like WhatsApp. The use of mobile technologies and their applications was encouraging in terms of teachers' readiness to adopt 4IR-based instructional strategies as they have benefits that include the provision of visible images of objects and scientific procedures, offering more flexibility for learning and supporting interactive collaboration both in and outside the classroom (Ma & Wang, 2017).

However, this leads to the question: what about the other participating teachers who are not currently implementing technology in their teaching practice? This could be because they do not have the skills to do so which requires training to upskill them. The non-implementation of technology in their current practice due to the lack of skills can be viewed as contributing negatively to their attitudes therefore stifling the adoption of 4IR-based instructional strategies which may affect their readiness to do so. The current researcher posits that through exposure to 4IR technology, teachers should be encouraged to infuse them into their teaching practice. The participating teachers' different levels of confidence in their abilities supporting or stifling the adoption of 4IR-based instructional strategies and varied use of technology in their current teaching practice further highlights the varying degrees of readiness established in Section 5.2.3 which discussed the lack of resources affecting the influence of the 4IR.

The engagement with other forces that shape attitudes also added to negativity in the participating teachers' attitudes towards their adoption of 4IR-based instructional strategies and may, therefore, further stifle their readiness to do so. The force of trust in the principal demonstrates this negativity. The participants did not anticipate management support which was corroborated when exploring it as a key dimension of the RRCM (Holt et al., 2007). This lack of management support further complicates this landscape of change. Although participants acknowledged its importance, there was a pervasive lack of confidence in receiving such support which demonstrated a mistrust in the principal. This scepticism aligns with Sekerka et al.'s (2009) observation that trust in management is crucial for facilitating organisational change. The apparent mistrust in management might consequently stifle the successful adoption of 4IR instructional methods, impacting both teaching strategies and learner outcomes.

This mistrust in the principal is linked to the force of the role of process factors as management is not expected to initiate and sustain a participative management approach. According to Terry and Callan (1997), participative management promotes a positive attitude towards change. Participation of individuals in the change process enables them to feel that they are affecting the change and develops feelings of acknowledgement as well as appreciation (Armenakis et al., 1993). Wanberg and Banas (2000) add that participative management increases employee commitment as participation promotes the belief that the change will bring about positive results. Lastly, the consequence of participation is that it ensures clarity through the elimination of ambiguity (Rafferty & Simons, 2006).

The action of distributing knowledge is linked to the action of participative management, management support and trusting the principal as the lack of these aspects suggests that the dissemination of knowledge may not be assured. The lack of both participative management and knowledge sharing suggests a negative attitude toward the change to adopting 4IR-based instructional strategies. According to Higgins (1996), attitudes develop immediately and are informed by the nature of the information provided. This suggests that knowledge sharing is important in developing a positive attitude toward change.

Associated with participative management and knowledge sharing relating to the need for teacher development initiatives is the factor of social influence of the UTAUT (Venkatesh et al, 2003). The participating teachers are not generally influenced by others when adopting a new behaviour but rather by the value of the new behaviour. This may support and stifle the adoption of 4IR-based instructional strategies. Teachers might recognise the value of the use of technology to improve their job performance and would, therefore, be more likely to adopt 4IR-based instructional strategies (Dwivedi et al., 2017). Stifling the adoption of 4IR-based instructional strategies is that teachers who do not value them might not adopt them. This aspect of not valuing them might even counteract decisions by important others such as management, curriculum planners and policymakers (Dwivedi et al., 2017). Contributing to the aspect of social influence and policy is that a teacher's reluctance to use technology is increased when policies are in place which call for the use of it (Koopman, 2022). Considering this, the current researcher posits that the value of 4IR-based instructional strategies in developing the skills required by learners in the 4IR should be fully explored with teachers through professional development initiatives and not simply stated in the curriculum policy document. This will ensure that their value resonates with the teachers resulting in their adoption.

Therefore, the readiness of teachers to adopt 4IR technologies can significantly influence their instructional methods and, by extension, learner development. Variability in teacher readiness across multiple dimensions highlights the complex interplay between individual beliefs, organisational support and the effective integration of 4IR technologies in educational settings.

The call for training acknowledged in the current research relates to the urgency to enhance teacher readiness to adopt 4IR-based instructional strategies. A lack of professional development contributes to the unsuccessful implementation of curriculum change, including pedagogical-technological transformation. For example, research has shown that the implementation of CAPS was negatively impacted by teachers' lack of knowledge and skills

required (Maharajh et al., 2016). Furthermore, Maddock and Maroun (2018) found that due to inadequate and inexpert teacher training which offered limited practical engagement in the classroom resulted in an unstable teaching and learning environment. Similarly, and as suggested by the participating teachers in the current research, poor teacher training for the integration of 4IR technologies could harm the integration.

The significance of teacher training is highlighted by UNESCO (2020) which argues that 60% of teachers globally expressed an under-preparedness for online teaching as they felt their training and support were deficient. In Sub-Saharan Africa, 50% of secondary teachers received minimum professional development as ICT skills were not included. Commenting on the importance of training, Wongwanich et al. (2015) state that training empowers teachers in preparation for them to successfully navigate educational change which speaks to the readiness of teachers. The participating teachers calling for and encouraging training speaks to their desire to be empowered to adopt 4IR-based instructional strategies as they acknowledged the need for it which further demonstrates their proficient understanding of the 4IR.

In terms of the training that is recommended, according to Iredale (2012), effective professional development needs to be relevant, meaningful, flexible and broad for change to occur in teachers' practice. Koopman (2022) adds that there is a need to provide science teachers with effective training. Singh-Pillay and Naidoo (2020) found that technical training received for online teaching and the misalignment of teaching pedagogy to the learning styles of students hindered online teaching. This supports the call for effective training.

While training is significant, basic daily non-exposure to the 4IR could also affect teacher readiness to adopt 4IR-based instructional strategies. This non-exposure to the 4IR is linked to the impact of the non-consultation of teachers in times of change. Jansen and Taylor (2003) criticised the non-exposure to new curricula, hindering their implementation. According to Sayed et al. (2021), the absence of meaningful engagement between the government and teachers influences the teaching and learning process. The current researcher posits that teachers be exposed to the 4IR to promote their understanding of it, thus improving their understanding of 4IR-based instructional strategies and ensuring a more holistic learning experience.

5.2.5 Factors Informing the Range of Proficiency in Understandings of 4IR-Based Instructional Strategies

Section 5.2.4 touched on and established the ranging proficiency of the participating teachers' understandings of 4IR-based instructional strategies. Other aspects also contribute to this understanding. The participating teachers' understanding of instructional strategies exhibits both competence and limitations. In terms of competence, they believed that instructional strategies are the different techniques, methods or ways that are used to convey information in the teaching and learning process. Instructional strategies could include traditional routine teacher-to-learner instruction, collaborative peer teaching or even learner-centred approaches in the form of guided teaching. These responses are consistent with the literature that defines instructional strategies as being methods procedures and activities used in teaching to facilitate it (Awotua-Efebo, 2007; Canady & Rettig, 1996; Obara & Okoh, 2005). Further evidence of the participating teachers' competence is the reference made to different types of instructional strategies.

The limitations of the participating teachers' understanding of instructional strategies are that they did not indicate that instructional strategies are planned, informed by the needs of the learners, used to motivate learners and are dependent on the environment which includes time, the physical setting and resources (Awotua-Efebo, 2007; Marzano, 2003; Obara & Okoh, 2005). This suggests that there may be gaps in the participants' understanding of instructional strategies. The participating teachers' limitations in their understanding of instructional strategies could be attributed to limited training and exposure. Their competence could be attributed to exposure to such strategies; however, this exposure may not have been sufficiently comprehensive to eliminate their limitations and secure a holistic understanding. This suggests that teacher training institutions might not have covered instructional strategies in a manner that would secure a deep understanding of such strategies. Further research is required to evaluate the curricula in teacher training and the extent to which such curricula address 4IR-based instructional strategies.

The participating teachers' proficiency in understanding 4IR-based instructional strategies varied due to differences in their competence, limitations and skills in instructional strategies, as previously identified in the call for training. This training necessity was shaped by their diverse skill levels, reflected in the differing degrees of integrating 4IR technology into their teaching practices. Section 5.2.4 highlighted the need for professional development initiatives

arising from this disparity. The primary objective of the research was to assess in-service Life Sciences teachers' alignment with 4IR-based instructional strategies. The varying levels of proficiency in these teachers' comprehension directly address this objective.

The differing skill levels, competencies and limitations among participating teachers in comprehending instructional strategies inform the alignment of their understanding with 4IR-based instructional strategies. Their alignment with these strategies varies, indicating differing levels of proficiency. This varied proficiency indicates varying levels of readiness, showcasing elements that both support and hinder the adoption of 4IR-based instructional strategies.

For instance, indicators of alignment in their grasp of 4IR-based instructional strategies involve participating teachers possessing the essential skills to implement these strategies in their current teaching approaches, along with demonstrating proficiency in instructional strategies that enhance their preparedness for adopting 4IR-based instructional methods. Conversely, signs of non-alignment in their comprehension of 4IR-based instructional strategies encompass participating teachers lacking the necessary skills and exhibiting limitations in their understanding of 4IR-based instructional strategies, impeding their readiness to adopt them. This finding necessitates a wider study to quantify teachers' understanding of 4IR and associated instructional strategies. If such a study corroborates the current findings, relevant professional development initiatives should be implemented to upskill teachers.

The participating teachers to a large degree identified skills related to the categories of global citizenship, innovation, creativity and technology and, to a lesser degree, interpersonal emotional intelligence skills to be developed by learners in the 4IR. This is consistent with the skills needed to be developed in the 4IR (Gray, 2016; P21CL, 2019; WEF, 2020). Notably, the skills selected are not well developed in the CAPS curriculum. This observation suggests a possible misalignment between the curriculum and the skills identified as necessary for the 4IR.

The skills selected by the participating teachers varied and a difference in their selection was thus observed. For example, innovation skills to be developed include the 4Cs of creativity, critical thinking, collaboration, and communication skills (P21CL, 2019). Concerning the 4Cs, the participating teachers mainly selected the skills of creativity and critical thinking as opposed to collaboration and communication which are associated with interpersonal emotional intelligence skills. To illustrate this point, one participating teacher mentioned the ability to manage people which is required for the 4IR (Gray, 2016). At face value, one can

identify the skill of managing people in the skill of leadership and responsibility. However, managing people skills suggests flexibility, social and cross-cultural skills, productivity and accountability. These skills include interpersonal emotional intelligence which involves empathy, cooperation, negotiation leadership and social awareness. These skills are required to cope and thrive in the 4IR. Therefore, the omission of critical 4IR skills could harm learner development and competitiveness.

Although the selection of skills varied, an overwhelming selection of the need and therefore the development of technological skills was observed. Reflecting on the aspect that the needs or skills required by learners to be developed are considered when designing instructional strategies suggests that, due to the dominance of technology skills in their selections, the participating teachers might design or select instructional strategies that predominantly develop such skills. There is a one-dimensional view of the skills required in favour of technology skills and at the expense of skills that are also required in the 4IR. The current researcher posits that teachers be made aware that using instructional strategies in the 4IR encompasses more than the integration of 4IR technology to develop technology skills. This is consistent with the acknowledgement in Section 1.1.4 which introduced the need for development of skills in 4IR-based instructional strategies.

The range of proficiency in the participating teachers' understandings of 4IR-based instructional strategies could also affect teacher readiness to adopt them in Life Sciences education. This was evident both in their selection and omission of different characteristics from the learning experiences in the 4IR. Although different, these characteristics are consistent with the quality of education proposed by the WEF (2020).

The differences among participating teachers in choosing the skills to be cultivated by learners and in defining the attributes of learning experiences within the 4IR also influenced the extent to which their understandings aligned with 4IR-based instructional strategies. These variations contributed to their diverse levels of proficiency in comprehending these strategies. Consequently, these differing levels of proficiency reflect varying degrees of readiness that encompass elements both conducive to and inhibiting the adoption of 4IR-based instructional strategies.

The skills selected by the participating teachers are consistent with the skills needed by learners in the 4IR as found in the literature (Gray, 2016; P21CL, 2019; WEF, 2020) and demonstrate

the alignment in their understandings of 4IR-based instructional strategies. This aspect may support their readiness to adopt 4IR-based instructional strategies. However, the participating teachers' overwhelming selection of technology skills compared to other skills may detract from the proficiency of their understanding of 4IR-based instructional strategies as this could result developing only such skills at the expense of the others. This point can be used to establish a possible non-alignment in their understanding of 4IR-based instructional strategies resulting in the non-holistic development of skills taking place. The current researcher posits that through exposure to 4IR-based instructional strategies which develops understanding, teachers will be better positioned to balance the acquisition of the skills required in the 4IR.

The very nature of the different characteristics of the 4IR's learning experiences selected contributes to the different degrees of alignment in their understanding of 4IR-based instructional strategies. These characteristics were consistent with quality education (WEF, 2020). The appropriate characteristics selected by the participating teachers demonstrate alignment of their understanding of 4IR-based instructional strategies which may support their readiness while the non-selection of the appropriate characteristics may stifle it. Teachers need to be made aware of the link between learning experiences and skills development. Where learning experiences are the tools that facilitate the development of such skills.

The participating teachers' understandings of instructional strategies showing both competence and limitations, their varied selection of both the skills to be developed by learners in the 4IR and the characteristics of 4IR learning experiences culminate to varying degrees of alignment in their understandings of 4IR-based instructional strategies. This varying degree of alignment informs their ranging proficiency informing varying degrees of readiness established in Section 5.2.3 which discussed the lack of resources affecting the influence of the 4IR and expanded on in Section 5.2.4 which discussed the need for professional development initiatives.

The reasoning used in Section 5.2.1 which explored the implications of the participating teachers' proficient understanding of the 4IR on the readiness to adopt 4IR-based instructional strategies can be applied to establish the implications of their ranging proficiency of their understanding of 4IR-based instructional strategies. As discussed in Section 5.2.1 the participating teachers' proficient understanding of the 4IR is encouraging to their readiness and this understanding develops a positive attitude towards the adoption of 4IR-based Instructional strategies. Considering this, therefore, due to the participating teachers' ranging proficiency of understanding of 4IR-based instructional strategies may support and stifle their readiness.

Participating teachers who have the skills (Section 5.2.4), competence in the understanding of instructional strategies, selected both the appropriate skills required by learners and the characteristics of the learning experiences in the 4IR, are aspects that may support the readiness to adopt 4IR-based instructional strategies. Converse to the status of these aspects may stifle their readiness.

5.2.6 Diverse Instructional Strategies

The current research reveals that participant teachers intend to adopt a diverse and unique set of instructional strategies for the 4IR. These intended instructional strategies rooted in experiential learning and self-development, align with the need for fostering pedagogical content knowledge and learner-centred approaches (Barenthien et al., 2023; WEF, 2020). The intention of the participating teachers to adopt a diverse set of instructional strategies addresses the key aims of the current research concerned with what instructional strategies in-service Life Sciences teachers intend to adopt in the 4IR and to what extent these instructional strategies are in line with 4IR-based instructional strategies. As these intended instructional strategies are unique to the participating teachers, this also contributes to their range of proficiency in understanding of 4IR-based instructional strategies addressing the key objective concerned with their understanding.

Notably, they all generally leaned towards the adoption of direct instruction, a teacher-centred approach, relied on in their current teaching practice. At first glance, the reliance on direct instruction which contrasts with a learner-centred approach detracts from their proficiency in their understanding of 4IR-based instructional strategies and demonstrates a non-alignment with them. A non-alignment may stifle the participating teachers' readiness to adopt 4IR-based instructional strategies. However, in terms of the selection of a diverse set of 4IR instructional strategies, direct instruction serves as a springboard or complements other strategies selected namely indirect and interactive instruction, experiential learning and independent study Akdeniz (2016). Teachers need to be made aware of this. The other strategies selected are conducive to a higher degree of learner involvement implying an appreciation of a more learner-centred approach encouraging the development of skills vital for 4IR (Gray, 2016; P21CL, 2019). Which caters for diversity among learners. Therefore, the varied instructional strategies chosen by participating teachers could be instrumental for learner development in the 4IR landscape, endorsing a complementary and holistic approach to teaching. The selection

of a diverse set of 4IR instructional strategies speaks to their alignment to 4IR-based instructional strategies which may support the readiness to adopt them.

Given that the participating teachers had not had professional development related to 4IR instructional strategies, the current researcher posits that the identified instructional strategies are derived from experience and self-development among them. This view is in line with teaching and learning experiences that foster the development of pedagogical content knowledge (Barenthien et al., 2023). The selection of a diverse set of instructional strategies is them catering for diversity among learners facilitating a learner-centred approach to learning (WEF, 2020). This diversity can be related to the different ways of learning (Section 2.6) suggests the proficiency of their understanding of 4IR-based instructional strategies.

Generally, instructional strategies lead to the development of skills among learners. It follows therefore that the teacher's instructional strategies should relate to the skills they want learners to develop. As previously stated in the current research indirect instruction was selected by participating teachers which engages with guided inquiry and problem-solving where learners are actively involved in hypothesising, investigating and observing. Which encourages their curiosity and interest to solve problems. Depending on the nature of the problem-solving activity allows for the development of flexibility, creativity and innovation skills as they explore different possible solutions (Akdeniz, 2016). By being flexible and creative learners may interact with others, therefore developing other skills which include people management, leadership and responsibility, coordination with others, interpersonal emotional intelligence, negotiating and social and cross-cultural skills.

Interactive instruction selected by the participating teachers involves the sharing of ideas allowing for the development of the skills of communication and collaboration. This communication and collaboration enable the learner's social skills to be developed where social skills are aligned with the skills required by individuals in or for the 4IR previously recognised in Section 2.2.4 (Gray, 2016; P21CL, 2019; WEF, 2020). Dependent on the nature of the activity adopted through interactive instruction other skills can be developed that include people management, negotiation and flexibility.

Experiential learning, selected by the participating teachers contributes to the development of the skills required in the 4IR as it involves a learner making inferences based on observing an activity, reflecting on it and then applying these inferences. According to McPherson-Geyser

et al. (2020), experiential learning involves a concrete experience, observation and reflection, the formation of abstract concepts and testing the implications of concepts. Through a problem-based activity learners would be required to reflect on their observations to produce inferences to solve the problem. This develops their critical thinking and problem-solving skills. The aspects of experiential learning suggest its applicability to the scientific method used in Life Sciences education which involves an activity where inferences are formulated and applied after observations and reflections have occurred. In solving the problem, a learner is encouraged to be creative and innovative therefore promoting the skill of flexibility in their approach to problem-solving. The skill of flexibility can be further developed through experiential learning taking place in and outside of the classroom which includes classroom experiments, field trips and field observations. Learners would need to be flexible to adjust to the different settings. The skills of communication and collaboration can be developed by their participation in their activity and the sharing of ideas to solve the problem.

Finally, independent study selected by the participating teachers contributes to the development of the skills required in the 4IR. These skills include due to the nature of independent study learners working on their own, flexibility, self-direction, productivity and accountability. Evidence of these skills being developed was expanded on by participating teachers who highlighted that independent study allows for the development of independent thinkers where the teacher guides and the responsibility rests with the learner which involves a learner-centred approach to learning.

The above discourse illuminates how participant teachers, through their unique selection of diverse instructional strategies, potentially contribute to learner development in the 4IR. The identified strategies range from direct to interactive instruction, incorporating experiential learning and independent study each offering distinct advantages in nurturing essential 4IR skills. Despite an initial leaning towards direct instruction, teachers exhibited a nuanced understanding that combined both teacher-centred and learner-centred approaches, serving as a comprehensive pedagogical toolset. These findings align with prior work on pedagogical content knowledge (Barenthien et al., 2023) and underscore the organic synthesis of these methods in the absence of formal 4IR-related professional development. The diversity in instructional methods enhances learner-centricity, an important tenet for 4IR education (WEF, 2020). Therefore, the instructional strategies selected by the teachers in the current research

not only demonstrate their pedagogical adaptability but also offer promising avenues for nurturing learners aptly for the 4IR landscape.

The participating teachers' selection of a diverse set of instructional strategies further informs their varying degrees of alignment in their understandings of 4IR-based instructional strategies which contributes to their ranging proficiency in their understanding. This indicates varying degrees of readiness that exhibit aspects which support and stifle the adoption of 4IR-based instructional strategies. Their selection of this diverse set of instructional strategies was consistent with catering for diversity among learners facilitating a learner-centred approach to learning (WEF, 2020). This demonstrates alignment and may support the readiness to adopt 4IR-based instructional strategies. The participating teachers have a propensity to use direct instruction exclusively and not to introduce or facilitate other more learner-centred instructional strategies demonstrating non-alignment with 4IR strategies. Therefore, it may be an aspect that stifles their readiness to adopt 4IR-based instructional strategies.

5.3 A FRAMEWORK FOR ENHANCING THE READINESS TO ADOPT 4IR-BASED INSTRUCTIONAL STRATEGIES

According to Razak et al. (2018), teachers' expertise, understanding and readiness concerned with the 4IR need to be aligned with it. Related to this point, Avelino and Ismail (2022), state that the expertise and readiness of teachers in infusing 4IR technologies into their teaching practices are central to teachers in the 4IR. Junid et al. (2019) add that the influence of the 4IR impacts requires a new array of skills. These works in tandem with the implications of the participating teachers' varying degrees of readiness, which exhibit aspects that may support and stifle the adoption to adopt 4IR-based instructional strategies, argue for the urgent enhancement of teacher readiness to adopt 4IR-based instructional strategies in Life Sciences education. To ensure relevance and competitiveness with international trends, the framework to be discussed aims to achieve.

5.3.1 Justification for the Framework

The primary aim of this research was to develop a framework for enhancing in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies. This framework is developed through the synthesis of findings concerning in-service Life Sciences teachers' understandings of 4IR-based instructional strategies; instructional strategies which in-service Life Sciences teachers intend to adopt in the 4IR; the extent to which in-service Life Sciences

teachers' understandings and intended practice of instructional strategies are in line with 4IR-based instructional strategies; and the readiness of in-service Life Sciences teachers to adopt 4IR-based instructional strategies. As shown in Section 5.2, significant findings have been made regarding the above. At this stage, a framework will be presented.

The framework aims to mitigate the implications of the aspects that may stifle the adoption of 4IR-based instructional strategies and strives to enhance the aspects that support their adoption. This is in line with human actions being informed by resisting and driving forces (Burnes, 2004; Riley, 2015). These forces apply to the aspects that stifle and support the adoption of 4IR-based instructional strategies respectively. The elimination and enhancement of the respective aspects may enhance the readiness to adopt 4IR-based instructional strategies. While absolute elimination may be difficult to achieve, the framework aims to reduce the impact of the stifling aspects.

The framework is also necessitated by the required transition to 4IR-based instructional strategies which has not been fully realised in South African education. Therefore, enhancing teacher readiness is urgent considering the number of years that have lapsed, which the framework attempts to accomplish as a proactive measure. The participating teachers calling for professional development initiatives further justifies the proposed framework as this call is the acknowledgement of the need to enhance readiness and the empowering nature of it in preparing them to successfully navigate educational change (Wongwanich et al., 2015). This call for professional development which the framework provides is therefore relevant as teachers were underprepared to enact change in past curriculum changes in South Africa due to the lack of professional development contributing to the unsuccessful implementation of the curriculum (Maddock & Maroun, 2018; Sayed et al., 2021; Singh-Pillay & Naidoo, 2020; Smit, 2001; UNESCO, 2020). Adding to the justification for the framework is that professional development is one of the support systems that need to be developed and sustained to facilitate the attainment of the skills required by learners in the 4IR (P21CL, 2019).

5.3.2 Outline of the Framework

The framework adopts a continuous professional development approach and considers the varying degrees of readiness to adopt 4IR-based instructional strategies in its formulation. Rendering it relevant, meaningful, flexible and therefore effective (Iredale, 2012; Koopman, 2022). Being a continuous professional development initiative, the framework applies to both

the preoperational phase and the operational phase of the curriculum implementation process (Ornstein & Hunkins, 2014). This is a recognition of the varying degrees of readiness as it relates to the mass implementation of 4IR-based instructional strategies hence the preoperational phase. Its applicability for the operational phase is due to sustaining and improving on the changed teachers' practices as well as for newly appointed teachers who have not been exposed to the tenets of 4IR-based instructional strategies.

The framework is informed by the Change Management Model for the implementation of change, a three-step process consisting of 1) *Unfreezing*, 2) *Moving* and 3) *Refreezing* (Lewin, 1947, Section 2.5.4). The *Unfreezing* step assumes that human behaviour is supported by forces and aims to make individuals transform their current practices (Burnes, 2004, Kritsonis, 2005). To change their current practice individuals, need to be aware of the need for the new action developing from an understanding of it and how it operates (Ornstein & Hunkins, 2014). This step overcomes an individual's resistance by unlearning old practices. According to Carson (2009), curriculum implementation commences with the necessary communication involving the engagement with the comfort of past practices of teaching and the oddness of new practices. It involves exposing teachers to and orientating them with several aspects of the curriculum to be implemented (Nyagah, 2001). This step creates motivation to learn new practices concerned with change.

The *Moving* step is essential as the *Unfreezing* step cannot be solely relied upon for change (Lewin, 1947). Intrinsic to this step is the change in practices of individuals denoted by a period when old practices are challenged and new ones are attempted (Burnes, 2004). It is a transition period involving a degree of confusion as individuals experiment and start to understand the new practices of implementing the change. According to Kritsonis (2005), *Refreezing* occurs once new practices have been implemented which were attempted in the *moving* step. According to Sansone et al. 2003, the *Refreezing* step is the establishment of new practices, the crystallisation of a fresh mindset and the initiation of comfort levels returning to prior levels. Robbins (2003) adds that this step is represented by the reinforcement of new practices, attitudes, knowledge and skills being infused into routines.

The terms used for each step relate to the phases of water simplifying the model and making it relatable as there is a basic and common understanding of the phases of water. This has been credited with the model being user-friendly and easy to understand. Features of the model are adapted in the framework to make it relevant to the findings of the current research. In line

with the model using relatable terms for easy understanding, the framework applies the analogy of entering a room and staying in it which requires the opening of a door therefore it is comprised of three stages namely: 1) *Unlocking*, 2) *Crossing the Threshold* and 3) *Relocking* (Figure 5.1).

Figure 5.1: The Framework to Enhance In-Service Life Sciences Teachers' Readiness to Adopt 4IR-Based Instructional Strategies
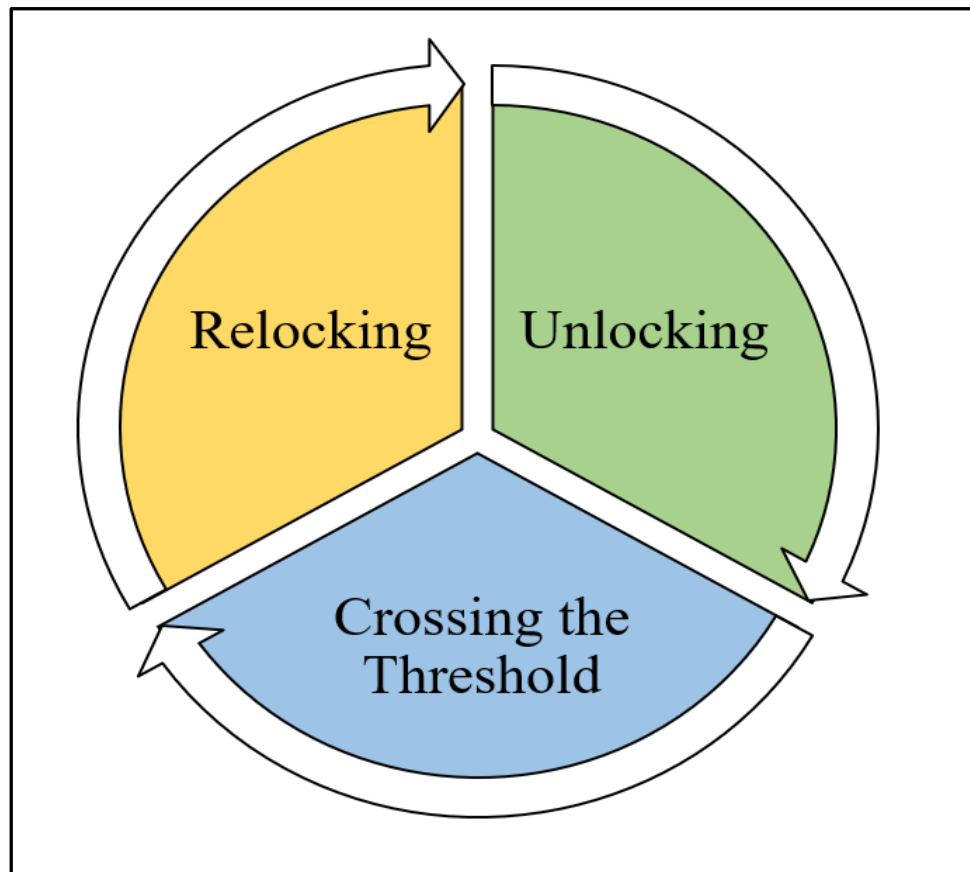
Briefly explained, *Unlocking* refers to "opening teachers up" to 4IR technologies and instructional strategies to which they may not have been exposed. In a sense, this stage "unlocks" a new world of both technologies and teaching methods to teachers. In the *Crossing the Threshold* stage, teachers who have been exposed to the 4IR technologies, experiment with 4IR-based instructional strategies as they "cross-over" to the new world of technology and teaching. In this stage, these technologies and related instructional strategies are no longer a theory, but a practical experience that teachers develop. During the *Relocking* stage, teachers' practical knowledge and skills are reinforced, such that they permanently adopt 4IR technologies and instructional strategies.

It must be noted that *Unlocking*, *Crossing the Threshold* and *Relocking*, are interdependent stages that occur concurrently rather than in a linear manner. This allows teachers to navigate between the stages depending on their needs making the framework flexible, self-paced and relevant. Having this option allows the teachers to have a first-hand experience of the type of learning to be incorporated into their 4IR teaching practice.

5.3.3 Stages and Application of the Framework

A closer look at the framework provided a detailed insight into each stage (Figure 5.2).

Figure 5.2: Detailed Representation of the Framework
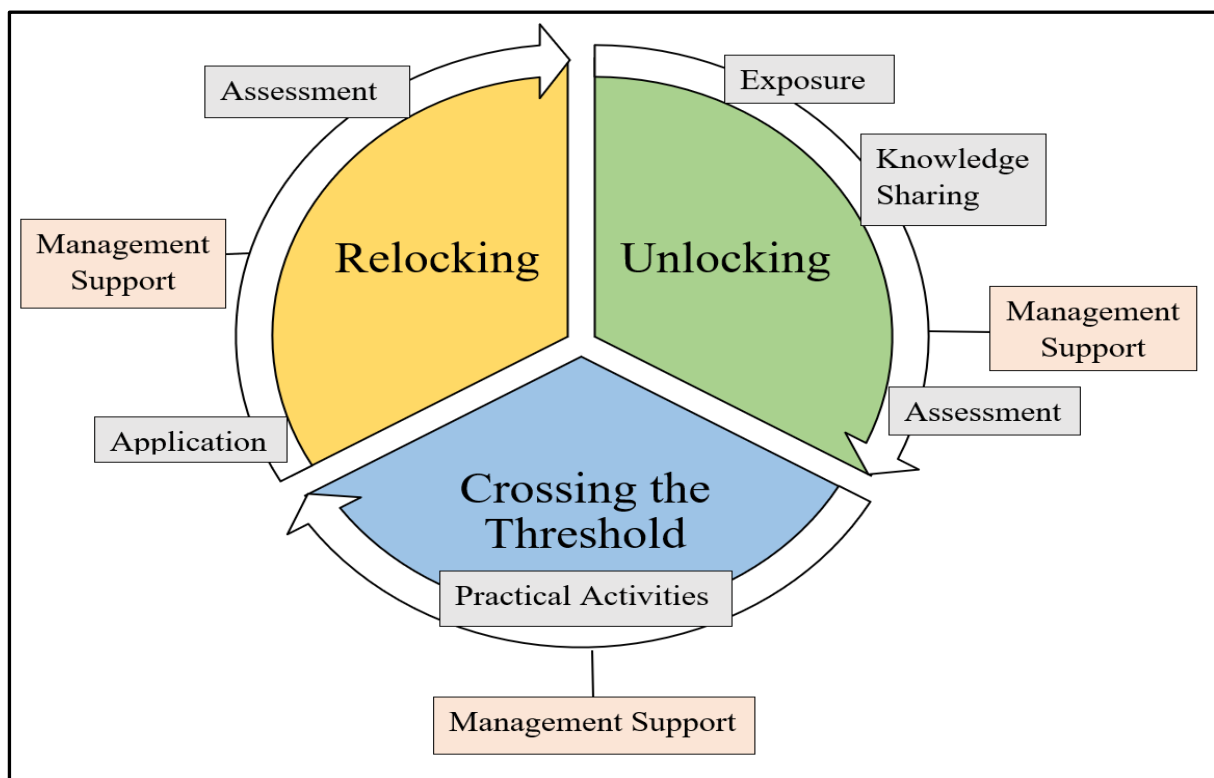
5.3.3.1 Unlocking

Exposure within the *Unlocking* stage, aligned with the *Unfreezing* step of the Change Management Model (Lewin, 1947), addresses the non-exposure of teachers to the 4IR and their exhibiting a range of proficiency in their understanding of 4IR-based instructional strategies which have the elements of non-alignment to them. Aspects teachers are exposed to in this stage include the understanding of the 4IR, its influence on society and education, the general understanding of instructional strategies, the skills required by learners in the 4IR, the diverse instructional strategies that will develop these skills and the characteristics of the learning

experiences. These aspects in part contributed to the non-alignment of the participating teachers' understandings and intended instructional strategies to 4IR-based instructional strategies informing varying degrees of readiness to adopt them. According to Riley (2015), a lack of knowledge is a force that resists change. Providing knowledge of the 4IR and its instructional strategies mitigates this lack of knowledge as a resisting force.

When exposing teachers to the 4IR and its instructional strategies a link is made between the influence of the 4IR and the change or modification of their instructional strategies. For example, teachers have a reliance on direct instruction in their teaching practice which is a teacher-centred approach to learning. This contrasts with the recommended learner-centred approach which considers the different learning styles of learners and therefore their diversity (WEF, 2020). Developing and promoting the understanding of the 4IR and 4IR-based instructional strategies also in part aids in developing a positive attitude towards the adoption of 4IR-based instructional strategies as understanding of a topic influences the attitude towards it. This responds in part to the finding that teachers do exhibit elements of negativity in their attitudes towards the change which is deemed to stifle it. A good understanding of a concept develops a positive attitude towards it (de Souza Barros & Elia, 1998).

According to Nyagah (2001), intrinsic to the framework, starting in the *Unlocking* stage involves seminars and workshops to get teachers' buy-in to the curriculum and its implementation. In these sessions, positive elements of the curriculum are presented, and the distribution of the necessary knowledge and skills empowers teachers to effectively implement the curriculum that includes 4IR-based instructional strategies. Through this distribution of knowledge related to the positive influence of the adoption of 4IR-based instructional strategies, it is envisaged will develop their value. The development of this value addresses the finding related to teachers who do not ascribe value to the adoption of 4IR-based instructional strategies as an aspect that stifles their readiness. According to Dwivedi et al. (2017), teachers who recognise the value of the use of technology to improve their job performance are more likely to adopt 4IR-based instructional strategies.

Another aspect of the *Unlocking* stage is that of knowledge sharing which should not be confused with exposing teachers to the aspects of the 4IR. This knowledge sharing is a form of consultation. One might consider exposing teachers to the curriculum to be implemented implies that it has been finalised rendering consulting teachers futile. However, curriculum implementation involves adaptive processes where variations in one facet of the

implementation process influence other linked aspects (Beacco et al., 2010; Yang, 2013). Consultation with teachers exposes curriculum designers to aspects that might have been overlooked. Consultation considers the aspects that hindered past curriculum implementations which included the lack of teacher consultation and involvement (Jansen & Taylor, 2003; Smit, 2001). More recently there was no meaningful engagement between the government and teachers in policy development (Sayed et al., 2021). Teachers were not consulted on aspects related to teaching and learning which included alternatives to the traditional practices used to deliver the curriculum.

The importance of consulting teachers is that the successful implementation of policy is dependent on healthy consultation with teachers (Viennet & Pont, 2017). Carvalho et al. (2020) and Sherif et al. (2020) add that consulting teachers in curriculum implementation is essential as they have a deep understanding of their learners and the community. Chow (2013) in advocating consultation, argues that a top-down approach is not ideal for educational change but rather teachers need to own the change through the consideration of contextual conditions. Consultation with teachers could result in a shared vision from shared decision-making which is a requisite for effective implementation of a curriculum (Bennet, 2007).

Included in the *Unlocking* stage is assessment. Here the teachers' understandings are assessed related to the various aspects they are exposed to. The assessment aspect is designed to determine the teacher's readiness to adopt 4IR-based instructional strategies. According to Hoover and Patton (2005), an effective curriculum implementation process has various strategies which include frequent audits of learners' learning progress. This strategy of frequent audits is applied to the teachers in the framework as the assessment serves as an audit of the *Unlocking* stage. The assessment is consistent with the term educational praxis which relates to an individual changing a condition through firstly, reflection and secondly by action which response to the reflection (Zhong, 2006). The assessment allows the teachers to reflect on the 4IR and its implications on their teaching practice. This reflection may bring about them embracing a change in their instructional strategies. Determining the readiness of teachers through their understanding allows for misconceptions of the 4IR and its instructional strategies to be addressed. Teacher readiness may be consistent with the findings of this current research, where the teachers had varying degrees of readiness which displayed aspects which are deemed to both support and stifle the adoption of 4IR-based instructional strategies. The assessment

also contributes to designing the appropriate activities for the *Crossing the Threshold* stage of the framework.

Throughout the framework the support of management is omnipresent. In the *Unlocking* stage, this includes management contributing to exposing the teachers to the aspects of the 4IR and facilitating the sharing of knowledge. If management is unable to expose the teachers themselves the support is them acquiring knowledgeable and adequately skilled individuals to do so. This considers the aspect of inadequate and inexpert training limiting practical engagement in the classroom hindering past curriculum changes (Maddock & Maroun, 2018). The support of management responds to the participating teachers of this current research valuing and welcoming it, feeling that it would not be forthcoming which emerged when exploring the dimensions of the RRCM (Holt., 2007). This lack of management support manifests the lack of trust in the principal and the acquisition of the role of process factors which are forces that negatively shape the teachers' attitudes (Kondakci et al., 2017). This negativity in attitudes stifles the adoption of 4IR-based instructional strategies. Management support in the *Unlocking* stage involves participative management and the distribution of knowledge which results in the teachers trusting the principal. This trust can develop positivity towards the adoption of 4IR-based instructional strategies. According to Cherry (2019), an attitude is reliant on experiences and environment which suggests it is dynamic and can be changed as new experiences and environments are experienced. This suggests that the support of management will go a long way in providing a new experience in terms of past experiences influencing their attitude.

5.3.3.2 Crossing the Threshold

The *Crossing the Threshold* stage, is aligned with the *Moving* step of the Change Management Model (Lewin, 1947) and responds to the findings that stifle the adoption of 4R-based instructional strategies which includes the dimension of self-efficacy in the RRCM (Holt et al., 2007). It emerged that teachers have different abilities to perform the new activity of adopting 4IR-based instructional strategies. This was corroborated when determining the attitudes of teachers in terms of the job outcomes forces concerned with workload (Kondakci et al., 2017). It was further shown that a deficiency exists in technological skills to infuse 4IR technologies in their teaching practice in terms of the factor of effort expectancy of the UTAUT (Venkatesh et al., 2003). According to Razak et al. (2018), concerning teacher readiness, teachers need to improve their technological skills through professional development interventions.

This stage includes the use of a combination of diverse instructional strategies by the facilitators to practically demonstrate how these instructional strategies can be adopted to facilitate the achievement of the skills required by learners in the 4IR (Gray, 2016; P21CL, 2019; WEF, 2020). In doing so the need for instructional strategies to be learner-centred is explored. Learner-centred to cater for the different ways of learning which allows for flexibility and self-pacing learning. This stage also includes technical aspects of using 4IR technology in the classroom and its use in a pedagogical sense (Singh-Pillay & Naidoo, 2020). The inclusion of the use of diverse instructional strategies, technical aspects and the pedagogical use of technology speaks to the framework as a professional development initiative being wide-ranging.

To further ensure the effectiveness of this stage and again wide-ranging. It includes both the development of technological skills and other skills required in the 4IR. This is due to 4IR-based instructional strategies encompassing more than just the development of technological skills. The other skills include and are not limited to creativity, collaboration, communication, critical thinking and problem-solving. The wide-ranging nature ensures that teachers do not only associate the development of technological skills with the 4IR. This assists teachers from under-resourced schools to appreciate that they too can develop skills in learners required for the 4IR even without or limited 4R technologies. This is relevant to South Africa as many rural schools lack the technological infrastructure to implement instructional strategies that integrate 4IR technology and therefore develop technological skills.

The use and value of diverse instructional strategies to secure a learner-centred approach to developing the skills required by learners in the 4IR makes the *Crossing the Threshold* stage "teacher-centred". Just as a learner-centred approach caters for a diverse learner cohort this stage caters for a diverse teacher cohort in terms of their varying readiness to adopt 4IR-based instructional strategies making it tailored to the needs of the teachers. This responds to the finding that teachers are at various levels in infusing 4IR technologies in their teaching practice as some teachers already use these technologies in their current teaching practice while others do not. The readiness of teachers who are already infusing 4IR technology in their teaching practice will be enhanced through the tailoring of the training.

During this stage, teachers are required to conduct lessons that incorporate 4IR-based instructional strategies, infusing 4IR technologies and diverse instructional strategies making the training interactive. Where there is a shift from a lecture method. Therefore, by fostering a

positive attitude toward them through experimentation with them teachers will be empowered to adopt 4IR-based instructional strategies. This practical and hands-on approach envisages a level of confusion as teachers experiment with the new practices.

The stage valuing the use of diverse instructional strategies and being hands-on is termed *blended learning²* or *blended learning 2.0*. These terms are used as this stage develops blended learning on two fronts. Firstly, the teachers' ability to blend electronic and traditional instruction which relates to blended learning (Graham, 2004). Secondly, valuing the use of diverse instruction promotes the blending of what is regarded as traditional instructional strategies. A suggested method of rolling out this stage and the framework could be the use of a MOOC and face-to-face instruction. Where there is a blending of technological instruction and traditional instruction which also blends a variety of traditional instructional strategies.

As in the *Unlocking* stage of the framework, the support of management is present in the *Crossing the Threshold* stage. The support includes management providing 4IR technologies for teachers to interact and experiment which responds to the factor of facilitating conditions found in the UTAUT (Venkatesh et al., 2003) as a lack of resources is deemed to stifle the adoption of 4IR-based instructional strategies. It emerged, that teachers operate in different infrastructural environments as they operate in schools that have resources, limited resources and no resources. The provision of resources can be done through management forging partnerships with education professionals, technology providers and telecom network operators to find innovative solutions to provide the necessary resources.

The flexibility of the framework is evident in that those teachers while practically experimenting and attempting 4IR-based instructional strategies who feel uncertain have the option of continuing with their experimentation or revisiting the aspects they were exposed to in the *Unlocking* stage.

5.3.3.3 Relocking

The *Relocking* stage, aligned with the *Refreezing* step of the Change Management Model (Lewin, 1947), involves the application and assessment of new practices, attitudes, knowledge and skills. The name of the stage suggests it is the relocking of practice by reinforcing the new practice if it is the desired one. The application aspect of the *Relocking* stage involves teachers adopting 4IR-based instructional strategies in their teaching practice. This adoption is in the form of piloting these new instructional strategies in an authentic classroom setting which

includes learners. This is in line with this stage reinforcing the new practices by infusing them into routines (Robbins, 2003). This stage allows for the infusion of 4IR-based instructional strategies by teachers to be self-paced which secures once again the flexibility of the framework. This flexibility can only be achieved if the framework is urgently implemented with consideration given to the timeline for the adoption of 4IR-based instructional strategies.

During this stage, there is the aspect of continuous assessment of the teaching practice of the teachers' instructional strategies. This assessment serves to provide feedback to the teachers to reinforce the desired practice when achieved. and includes both theory and practice. Various forms of theoretically assessing the teachers include group discussions, poster presentations, lesson plans and written assessments. Practically assessing the teachers includes role plays and actual lesson presentations related to the implementation of 4IR-based instructional strategies. The rationale for the assessment in this component is also rooted in it being included in the *Unlocking* stage of the framework which relates to frequent audits in assisting the teachers with educational praxis.

The assessment in this stage also establishes the degree to which the aims of the professional development were achieved. If a teacher has not acquired the competencies to relock the practice, the framework allows for such teachers to revisit it. Management support is present during this aspect of assessment providing feedback used in deciding the appropriate stage the teacher needs to revisit. Management also provides the necessary resources for the adoption of 4IR-based instructional strategies. The assessment aspect informing both the achievement and non-achievement of the aims of the framework provides feedback that is used to improve how it is delivered. This leads to enhancing the professional development experienced by teachers developing the holistic readiness of teachers to adopt 4IR-based instructional strategies. This enhancement of the professional development experienced by the teachers is consistent with being continuous (Koopman, 2022).

The inclusion of assessment in the *Relocking* stage is the product of reflecting on the theories that combined to form the theoretical framework of this current research. In both the RRCM (Holt., 2007) and the UTAUT (Venkatesh et al., 2003) an individual's readiness to implement a new behaviour is determined and stopped at that point. The proposed framework goes further by assessing the new behaviour.

5.3.4 Implications of the Framework

As the framework is a professional development activity the implications of it are considered through a professional development lens. Effective professional development activities have a positive impact on teaching quality, self-efficacy, teaching beliefs, student outcomes and overall job satisfaction (Fabriz et al., 2021; Heinonen et al., 2022; Ödalen et al., 2019; Vilppu et al., 2019;). The framework involving several educational stakeholders namely teachers, management, individuals with the expertise and the private sector being called upon to assist with resources suggests that it is a team-based professional development activity. The benefits of this are the promotion of teacher reflection on their practice, learner-centred teaching and pedagogical knowledge (Gast, 2017). It is envisaged that the framework being meaningful, flexible and wide-ranging therefore effective will enhance teachers' readiness to adopt 4IR-based instructional strategies through the activities within its stages, culminating in the adoption of them in teachers' teaching practice. This adoption would be due to an improvement in teachers' self-efficacy, their teaching beliefs and overall job satisfaction contributing to their attitudes to embrace 4IR-based instructional strategies. This adoption has a positive impact on the effectiveness of the teachers in the teaching and learning process in the 4IR.

The framework facilitating quality teaching and the achievement of learner outcomes assists in the attainment of the vision of educational policy (curricula) in the 4IR. Through the positive influence on teachers and teaching the framework will encourage governmental educational authorities to improve and intensify their professional development policy for teachers. As the fruits of the framework will be appreciated. Added to this, the framework could serve as a blueprint or an initiation of discourse for the development of more innovative future professional development initiatives.

The implications of the framework can also be extended to teacher training as the assessment of teacher readiness to adopt 4IR-based instructional strategies and their adoption can inform teaching training institutions' programmes related to their content and delivery. Programmes can include aspects that provide for the holistic development of pre-service teachers concerning 4IR education.

5.4 CONCLUSION

This chapter discussed the findings of the study. Theories that underpin the study were used to confirm or refute them. The discussions led to a discussion concerned with the participating

teachers exhibiting a varying readiness to adopt 4IR-based instructional strategies displaying aspects that are deemed to support or stifle their adoption. This was considered in developing a framework to enhance in-service Life Science teachers' readiness to adopt 4IR-based instructional strategies which is a professional development initiative. A framework that is inspired by Lewin's Change Management Model for the implementation of change which addresses the findings of the current research.

The next chapter serves to conclude the current research by providing a summary of each chapter, the findings related to the research questions and recommendations based on these findings.

CHAPTER 6: ARRIVING AT JOURNEY'S END

"The people who are crazy enough to believe they can change the world are the ones who do."

Steve Jobs

6.1 INTRODUCTION

The preceding chapter discussed the findings of the current research and proposed a framework to enhance in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies. This chapter summarises each chapter, and the findings related to the research questions and presents recommendations for governmental educational authorities, Life Sciences teachers directly and further research.

6.2 SUMMARY OF THE STUDY

Chapter 1 provided the background to the current research to contextualise it. It explored the influence of the 4IR on society, and education and established the problem to which it responds. Which is rooted in the factors that hinder educational change in general and relevant to South Africa the implementation of CAPS and COVID-19. The main research question was to develop a framework to enhance in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies. Developing this framework entailed responding to research sub-questions. These research sub-questions involved the in-service Life Science teachers' understandings of 4IR-based instructional strategies, the instructional strategies they intend to adopt in the 4IR, the extent to which these understandings of 4IR-based instructional strategies and their intended instructional strategies are in line with 4IR-based instructional strategies. These research sub-questions contributed to responding to the research sub-question concerned with enhancing the readiness of in-service Life Sciences to adopt 4IR-based instructional strategies. Chapter 1 also introduced 4IR-based instructional strategies and the rationale for the current research, including the gap in the research and addressing its problem.

Chapter 2 provided the theoretical underpinnings of the current research by exploring the broad themes and theories that are pertinent to it. It described the key aspects found in its title which include the 4IR, education and instructional strategies for it and justified the theoretical framework employed which frames the readiness to change. The theoretical framework that is comprised of the RRCM (Holt et al., 2007), the role of attitudes in the readiness for change

(Kondakci et al., 2017), the influence of the 4IR understandings on the readiness for change and the UTAUT (Venkatesh et al., 2003).

Chapter 3 presented the research methodology adopted to address the main research question facilitated by addressing the research sub-questions to achieve the aims of the current research. It identified and justified the selection of the various aspects of the research methodology which included the interpretive paradigm, the qualitative approach, a case study design and the research methods. These research methods include purposive and convenience sampling. The sample, who were in-service Life Sciences teachers was fully described. The data collection instruments namely, an open-ended questionnaire, a semi-structured interview and document analysis were described and substantiated in terms of their applicability. Guided analysis was selected to analyse the data generated. The chapter also presented the measures employed to secure trustworthiness and the ethical aspects of the current research.

Chapter 4 presented the results for the research sub-questions of the current research. These results were corroborated and substantiated by verbatim evidence from the multiple data collection instruments.

Chapter 5 discussed the results presented in Chapter 4. The discussion of the results generated findings. This involved applying the theories that underpin the study to validate or invalidate them. These discussions of the findings contributed to the development of a framework to enhance in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies.

6.3 SUMMARY OF FINDINGS

Table 6.1 presents a summary of the findings and the aspects that inform them relevant to each research sub-question considered in developing a framework to enhance in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies.

Table 6.1: A Summary of the Findings and the Aspects Informing them

Research sub-questions	Finding/s and aspects informing it
1. What is in-service Life Sciences teachers' understanding of 4IR-based instructional strategies?	Teachers exhibit a range of proficiency in their understanding of 4IR-based instructional strategies. Informed by the teachers': • Understanding of the 4IR • Varying understandings of the term "instructional strategies" • Varying selections of both the skills to be developed in the 4IR and the characteristics of the learning experiences that will develop such skills • Intention to adopt diverse instructional strategies
2. What instructional strategies do in-service Life Sciences teachers intend to adopt in the 4IR?	Teachers intend to adopt diverse instructional strategies Informed by teachers: • Selection of direct instruction, indirect instruction, interactive instruction, experiential learning and independent study Teachers exhibit a reliance on direct instruction
3. To what extent are in-service Life Sciences teachers' understandings of 4IR-based instructional strategies and their intended instructional strategies in line with 4IR-based instructional strategies?	Teachers exhibit varying degrees of alignment in both their understanding of 4IR-based instructional strategies and their intended instructional strategies

		Informed by teachers:
		• Varying understandings of the term "instructional strategies"
		• Varying selections of both the skills to be developed in the 4IR and the characteristics of the learning experiences that will develop such skills
		• Intention to adopt diverse instructional strategies
4.	What is the readiness of in-service Life Sciences teachers to adopt 4IR-based instructional strategies?	Teachers exhibit varying degrees of readiness to adopt 4IR-based instructional strategies. Displaying aspects which are deemed to both support and stifle their adoption.
		Informed by:
		• Findings of research sub-questions 1, 2 and 3.
		• The RRCM (Holt et al., 2007), the participants' attitudes towards the adoption of 4IR-based instructional strategies (Kondakci et al., 2017) and the UTAUT (Venkatesh et al., 2003).

6.4 RECOMMENDATIONS

The recommendations are informed by the findings, their discussions and the framework developed to enhance in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies. They are divided into three categories namely for governmental educational authorities, Life Sciences teachers directly and further research.

6.4.1 Recommendations for Governmental Educational Authorities

To address the different levels of resource availability at schools, governmental educational authorities need to urgently conduct full-scale infrastructural audits of schools to determine if schools as a collective have the necessary resources to adopt 4IR-based instructional strategies. The results of this should be seriously considered by policymakers and curricula planners/designers when deciding the 4IR-based instructional strategies to include. This is necessary in the interest of securing quality and equality in the classroom delivery of standardised curricula in the 4IR. Where all learners are exposed to the same quality of delivery. Leading from this audit the procurement of the lacking resources should be prioritised to implement the standardised curriculum. Measures to procure resources include the forging of partnerships with the private sector to assist with technological devices and Internet connectivity which includes data. Reflecting on the rate of procurement of resources, governmental educational authorities need to decide on achievable goals for the resources to be available for all schools and implement the possible staggered adoption of 4IR-based instructional strategies based on the equal availability of resources.

It is recommended that governmental educational authorities conduct initial and continuous professional development activities such as seminars and workshops. These activities are designed to expose teachers to the 4IR and its influence on their teaching practice in terms of the instructional strategies that will develop the skills learners need. The exposure also includes the latest developments in technological advances hence professional development is continuous. This will allow teachers to gain confidence garnering a positive attitude toward and embracement of 4IR-based instructional strategies. Enhancing teacher embracement is governmental educational authorities in these professional development activities consulting with teachers regarding the adoption of 4IR-based instructional strategies in the curriculum making them feel a part of the decision-making process.

It is further recommended that governmental educational authorities develop collaborative relationships with teacher training institutions. This will ensure that they are working together to develop teachers who are competent to adopt 4IR-based instructional strategies. Subsidies or incentives be made available to teachers who attend developmental external short learning programmes focusing on 4IR learning. Linked to incentivising, is securing highly skilled human resources with an intense national and international recruitment drive to attract teachers with the expertise to infuse 4IR technology in their teaching practice. This can be extended to

postgraduate students in the field of technology who want to become teachers where they can complete a postgraduate certificate in education as part of developing their pedagogy.

Finally, the inclusion of the topic "Technology Studies" in the compulsory subject of Life Orientation to expose learners to 4IR technology. Various aspects of technology requiring different levels of cognitive ability can be included in line with the progression of learners through the grades. Content in this topic is not intended to be a repetition of the content included in stand-alone subjects such as Coding and Robotics which attempt to address the influence of the 4IR.

6.4.2 Recommendations for Life Sciences Teachers

It is recommended that Life Sciences teachers attend professional development activities conducted by governmental educational authorities that engage them with the 4IR. This engagement involves the applicable teaching methodology including the development of competence in the technical aspects of 4IR technology such as the setting up and use of projectors and such devices. In conjunction with this, they should also attend external short learning programmes that explore similar aspects covered in the recommended professional development activities. Attending these types of learning activities serves to enhance their understanding of the 4IR as their delivery might be different catering to their different learning styles. Teachers who attend external short learning programmes will be well-positioned to share knowledge with other colleagues opening pathways for constructive discussions and collaborations. Finally, teachers should reflect on their current practice to assess if it is learner-centred or teacher-centred. This reflection will be valuable in initiating changes if necessary.

6.4.3 Recommendations for Further Research

It is recommended that similar large-scale mixed-method research be conducted involving other provinces, districts and learning phases to address the generalisability of this current research, a limitation of qualitative research. Further aspects that can be different in this similar research relate to firstly, the sample as the current research is overwhelmingly dominated by female teachers. This is in line with female teachers dis-proportionally outnumbering males in schools (Davids & Waghid, 2020). However, this is extreme in terms of the current makeup of the teaching population in South Africa where females account for 70 per cent of it (Wills & Bohmer, 2023). This will enhance the representation of male teachers and their voice will inform findings to a greater extent securing a deeper understanding of multiple realities.

Secondly, lesson observations can be added in this similar research as a data collection instrument. According to Robson (2002), an observation "enables the researcher to look afresh at everyday behaviour that otherwise might be taken for granted, expected or go unnoticed" (p.310). The selection of lesson plans facilitated the collection of data agreeing with ethical considerations. Ethical clearance applied to conduct the current research was done during COVID-19 where importance was placed on the safety of individuals. The addition of observations is not only confined to the value of them in generating findings which demonstrate a deeper understanding but they also secure greater credibility of these findings due to an added layer concerned with triangulation.

Thirdly, the moderating factors of the UTAUT (Venkatesh et al., 2003) namely, gender, age and experience be included in the analysis of the data collected. This will enhance the findings related to aspects represented in the greater population of teachers. These differences in similar research may unearth different findings used to expand on the framework discussed in Section 5.3.

6.6 CONCLUSION

Countries across the globe experience the influence of the 4IR on education differently depending on the stage of planning and implementation of educational policy. Like many developing countries South Africa is still in its infancy of educational policy development related to the 4IR. The current research addressed its main research question by developing a framework for enhancing in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies due to the influence of the 4IR which achieved its primary aim. The framework found in Section 5.3 responds to the argument that urgent enhancement of teacher readiness is required. This argument is informed by the findings of the research sub-questions and the fulfilment of the respective secondary aims of the current research in conjunction with consideration of the time that has elapsed since the inception of the 4IR.

The overall finding applied to develop the framework for enhancing in-service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies is that these teachers exhibit varying degrees of readiness to adopt 4IR-based instructional strategies which displays elements that support and stifle their adoption. Contributing to this finding was the teachers' range of proficiency in their understanding of 4IR-based instructional strategies which addressed the first research sub-question and its related aim. This finding was informed by the

teachers' understanding of the 4IR, their varying understandings of the term "instructional strategies", their varying selections of both the skills to be developed in the 4IR and characteristics of the learning experiences that will develop such skills, and their intention to adopt diverse instructional strategies. The teachers' intention to adopt diverse instructional strategies addressed the second research sub-question and its related aim.

Findings to the first and second research sub-questions addressed the third research sub-question and its related aim. Teachers displaying a ranging proficiency in their understandings of 4IR-based Instructional strategies and their intention to adopt diverse instructional strategies demonstrated a varying degree of alignment in both their understanding of 4IR-based instructional strategies and their intended instructional strategies. By virtue of the varying degree of readiness are elements that support and stifle the adoption of 4IR-based instructional strategies. These elements contributed to the varying degree of alignment in both their understanding of 4IR-based instructional strategies and their intended instructional strategies (research sub-question three). For example, supporting the adoption includes the teachers' proficient understanding of the 4IR and its influence on teaching practices, the varying levels of competence in their understanding of the term "instructional strategies", their selection of the appropriate 1) skills to be developed in the 4IR by learners, 2) the characteristics of the learning experiences that will develop such skills and their intention to adopt diverse instructional strategies which implies a more learner-centred approach to learning. A recommendation for learning in the 4IR (WEF, 2020).

Stifling the adoption of 4IR includes limitations in their understanding of the term "instructional strategies", their non-unanimous selection of the skills to be developed in the 4IR by learners, their selection of inappropriate characteristics of the learning experiences that will develop such skills and their reliance on direct instruction when intending to adopt diverse instructional strategies which contrasts with a more learner-centred approach to learning.

Further informing the varying degrees of teacher readiness to adopt 4IR-based instructional strategies was the theoretical framework which framed and determined readiness. The theoretical framework comprised of the RRCM (Holt et al., 2007), the participants' attitudes towards the adoption of 4IR-based instructional strategies (Kondakci et al., 2017), the influence of the 4IR understandings on the readiness for change and the UTAUT (Venkatesh et al., 2003). Supporting the adoption includes teachers believing that the change is necessary, see the value in it in terms of it benefitting them in the form of their personal growth and improved learner

performance enhancing their general positive toward change. Another supporting element is that some of the teachers currently have the skills and function in schools that have the resources to already infuse 4IR technology into their teaching practice. The teachers who do not have the skills and resources are elements that stifle the adoption of 4IR-based instructional strategies. Adding to these stifling elements include teachers' mistrust in management to conduct its associated roles in change which include participative management and knowledge distribution which socially influence individuals to value the change fostering a positive towards it.

The current research in responding to its main research question and achieving its primary aim established and confirmed that aspects that hindered the implementation of past curricula which, informed the problem statement, to a degree still prevail. This is both disturbing and encouraging for the adoption of 4IR-based instructional strategies. Where the framework proposed, a professional development initiative attempts to urgently mitigate the disturbing and enhance encouraging aspects in the interest of teacher readiness. Finally, the knowledge gained which is considered in developing the framework to enhance the readiness of in-service Life Sciences teachers readiness to adopt 4IR-based instructional strategies may firstly, contribute to the limited knowledge related to teacher readiness and secondly, raise awareness of the influence of the 4IR on teaching practice to meet its demands.

REFERENCES

Agumba, H., Modiba, M., & Akala, B. (2019). *Teachers' preparation for the fourth industrial revolution- A case of South Africa*. Conference paper. Retrieved from: ICET2019-094TeacherspreparationforthefourthindustrialRevolution-AcaseofSouthAfrica (8).pdf

AgwuUdu, D. (2017). Comparative effects of individualized and cooperative learning instructional strategies on senior secondary school students' academic achievement in organic chemistry. *Electronic Journal of Science Education, 22*(2), 1-14. Retrieved from: https://eric.ed.gov/?id=EJ1188015

Ajzen, I. (1991). The theory of planned behavior. *Organizational behavior and human decision processes*, *50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Ajzen, I. (1993). Attitude theory and the attitude-behavior relation. In D. Krebs & P. Schidt (Eds.), *New directions in attitude measurement* (pp. 41–57). Walter de Gruyter.

Ajzen, I. (2005). *Attitudes, personality, and behavior* (2nd ed.). Open University Press.

Akdeniz, C. (2016). *Instructional process and concepts in theory and practice*. Springer.

Alade, I. (2011). Trends and issues on curriculum review in Nigeria and the need for paradigm shift in education practice. *Journal of Emerging Trends in Educational Research and Policy Studies*, *2*(5), 325–333.

Alhojailan, M. (2012). Thematic analysis: A critical review of its process and evaluation. *West East Journal of Social Sciences*, *1*(1), 39–47.

Allen, I., & Lester, S. (2012). The impact of a college survival skills course and a success coach on retention and academic performance. *Journal of Career and Technical Education, 27*(1), 2012–2020.

Alsubaie, M. (2016). Curriculum development: Teacher involvement in curriculum development. *Journal of Education and Practice*, *7*(9), 106–107.

Andrini, V. (2016). The effectiveness of inquiry learning method to enhance students' learning outcome: A theoretical and empirical review. *Journal of Education and Practice, 7*(3), 38–42.

Aoun, J. (2017). *Robot-proof: Higher education in the age of artificial intelligence*. MIT Press.

Apple, M. (2004). *Ideology and curriculum* (3rd ed.). Routledge Falmer.

Armenakis, A., & Bedeian, A. (1999). Organizational change: A review of theory and research in the 1990s. *Journal of Management*, *25*, 293–315.

Armenakis, A., & Harris, S. (2002). Crafting a change message to create transformational readiness. *Journal of Organisational Change Management*, *15*(2), 169–183.

Armenakis, A., Harris, S., & Mossholder, K. (1993). Creating readiness for organisational change. *Human Relations*, *46*(6), 681–702.

Atkin, M., & Black, P. (2003). *Inside science education reform: A history of curricular and policy change*. Teachers College Press.

Audu, C. (2018). Influence of teaching styles on students' achievement and interest among biology students in secondary schools in Taraba State Nigeria. *Advances in Social Sciences Research Journal, 5*(5), 164–172.

Avelino, N., & Ismail, H. (2022). Teachers' levels of knowledge and readiness in integrating 4IR technologies: The primary ESL classroom context. *International Journal of Learning, Teaching and Educational Research, 21*(3), 415–433. https://doi.org/10.26803/ijlter.21.3.22

Awotua-Efebo, E. (2007). *Effective teaching: Principles and practice.* Paragraphics.

Babbie, E. (2007). *The practice of social research* (11th ed.). Thomson Wadsworth.

Badmus, S., Ganiyu, B., Abdulrasaq, H., & Musa Mohammed, S. (2019). Effects of webquest on secondary school biology students achievement in cell division in IIorin. *Humanities and Social Sciences Letters, 7*(2), 64–73.

Bak, N. (2004). *Completing your thesis: A practical guide*. Van Schaik.

Bamidele, E., & Yoade, F. (2017). Effects of modes of computer animation instructional packages on students' achievement in Osun state secondary schools' biology. *International Journal of Innovation and Research in Educational Sciences, 4*(4), 496–501.

Bandura, A. (1997). *Self–efficacy: The exercise of control*. Freeman and Company.

Barenthien, J., Firbranz, A., Todorova, M., Moller, K., & Steffensky, M. (2023). Development of professional vision and pedagogical content knowledge during initial teacher education. *International Journal of Educational Research*, *119*, 102186. https://doi.org/10.1016/j.ijer.2023.102186

Baškarada, S. (2014). Qualitative case study guidelines. *The Qualitative Report, 19*(40), 1–18.

Bates, A. (2015). *Teaching in a digital age* (2nd ed.). Tony Bates Associates.

Baxter, J. (1991). A constructivist approach to astronomy in the national curriculum. *Physics Education*, *26*, 38–45.

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report, 13*(4), 544–559. Retrieved from: http://iopscience.iop.org/0031 - 9120/26/1/007

Beacco, J., Byram, M., Cavalli, M., Coste, D., Cuenat, M., Goullier, F., & Panthier, J. (2010). *Guide for the development and implementation of curricula for plurilingual and intercultural education.* Council of Europe.

Beastly, T., & Peters, M. (2013). The creative university: Creative social development and academic entrepreneurship. In M. Peters & T. Beastly (Eds.), *Re-imagining the creative university for the twenty-first century* (pp. 3–26)*. Sense.

Bell, J. (2005). *Doing your research project: A guide for first time researchers in education, health and social science* (4th ed.)*. Open University Press.

Bennett, D. (2007). *Teacher efficacy in the implementation of new curriculum supported by professional development* (Doctoral thesis, The University of Montana, Missoula,

United States of America).
https://scholarworks.umt.edu/cgi/viewcontent.cgi?article=1965&context=etd

Bernstein, B. (1974). Sociology and the sociology of education: A brief account. In J. Rex (Ed.), *Approaches to sociology: An introduction to major trends in British sociology* (pp. 145–159). Routledge & Kegan Paul.

Betoret, F. (2006). Stressors, self-efficacy, coping resources, and burnout among secondary school teachers in Spain. *Educational Psychology, 26*(4), 519–539. https://doi.org/10.1080/01443410500342492

Blundell, E. (1998). *Document analysis as a qualitative research technique in assessing oral health policy*. Retrieved from: http://icoh.denistry.dal.ca/DocAnalysisSchool.pdf

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.

Bosch, C. (2017). *Promoting self-directed learning through the implementation of cooperative learning in a higher education blended learning environment* (Doctoral thesis, North-West University). https://repository.nwu.ac.za/handle/10394/26102

Bosch, C., Mentz, E., & Reitsma, G. (2019). Integrating cooperative learning into the combined blended learning design model: Implications for students' intrinsic motivation. *International Journal of Mobile and Blended Learning, 11*(1), 58–73. https://doi.org/10.4018/IJMBL.2019010105

Bowen, G. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, *9*(2), 27–40.

Boyer, S., Edmondson, D., Artis, A., & Fleming, D. (2014). Self-directed learning: A tool for lifelong learning. *Journal of Marketing Education*, *36*(1), 20–32. https://doi.org/10.1177/0273475313494010

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101.

Brickhouse, N. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education*, *41*(3), 53–62.

Brockett. R., & Hiemstra, R. (1991). *Self-direction in adult learning: Perspectives on theory, research, and practice*. Routledge.

Brown, P., & Keep, E. (2018). Rethinking the race between education & technology. *Issues in Science and Technology*, *35*(1), 31–39.

Brown–Martin, G. (2017). *Education and the fourth industrial revolution*. Retrieved from: https://www.groupemediatfo.org/wp-content/uploads/2017/12/FINAL-Education-and-the-Fourth-Industrial-Revolution-1-1-1.pdf

Buckenmeyer, J. (2010). Beyond computers in the classroom: Factors related to technology adoption to enhance teaching and learning. *Contemporary Issues In Education Research*, *3*(4), 27–35.

Bunniss, S., & Kelly, D. (2010). Research paradigms in medical education research. *Medical Education*, *44*(4), 358–366.

Burnes, B. (2004). Kurt Lewin and the planned approach to change: a re-appraisal. *Journal of Management Studies*, *41*(6), 977–1002.

BusinessTech. (2022, October 22). *New subjects set for schools in South Africa next year.* Retrieved from: https://businesstech.co.za/news/technology/637199/new-subjects-set-for-schools-in-south-africa-next-year/

Butler-Adam, J. (2018). The fourth industrial revolution and education. *South African Journal of Science*, *114*(5), 1.

Bybee, R. (1993). *Reforming science education.* Teachers College Press.

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Powell, J., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness*. BSCS.

Cambridge University Press. (n.d.). Change. *Cambridge dictionaries online*, 2022. Retrieved January 15, 2022, from: https://dictionary.cambridge.org

Canady, R., & Rettig, M. (Eds). (1996). *Teaching in the block: Strategies for engaging active learners*. Eye on Education.

Cantrell, D. (2001). *Alternative paradigms in environmental educational research: The interpretive perspective.* Retrieved from: http://www.edu.uleth.ca/ciccte/naceer.pgs/pubpro.pgs/alternate/pubfiles/08.Cantrell.fin.htm

Carson, D., Gilmore, A., Perry, C., & Gronhaug, K. (2001). *Qualitative marketing research*. Sage.

Carson, T. (2009). Re-thinking curriculum change from the place of the teacher: Teacher identity and the implementation of curriculum in China. In A. Tero & R. Eero (Eds.). *Reforming curriculum discourses: Subjects, society and curriculum* (pp. 231–224). Sense.

Carvalho, S., Rossiter, J., Angrist, N., Hares, S., & Silverman, R. (2020). *Planning for school reopening and recovery after COVID 19: An evidence kit for policymakers.* Retrieved from: https://www.cgdev.org/sites/default/files/planning-school-reopening-and-recovery-after-covid-19.pdf

Castells, M. (2011). *The rise of the network society: The information age: Economy, society, and culture* (Vol. 1). John Wiley & Sons.

Chandler, A. (1990). *Scale and scope: The dynamics of industrial capitalism*. Harvard University Press.

Cherry, K. (2019). *Attitude and behavior in psychology*. Retrieved from: https://www.verywellmind.com/what-is-self-esteem-2795868

Chow, A. (2013). Managing educational change: A case of two leadership approaches. *International Journal of Leadership in Education*, *16*, 34–54.

Christiansen, I., Bertram, C., & Land, S. (2010). *Understanding research* (3rd ed.). University of KwaZulu-Natal, Faculty of Education.

Chrysostomou, S. (2004). The interdisciplinary approaches in the new curriculum in Greece: A focus on music education. *Arts Education Policy Review*, *105*(5), 23–29.

Chukwu, J., & Arokoyu, A. (2019). Effects of jigsaw-puzzle instructional strategy on secondary school students' performance on growth as a concept in biology in Abia State. *Advances in Research*, *20*(1), 1–6.

Clarà, M., & Barberà, E. (2013). Learning online: Massive open online courses (MOOCs), connectivism, and cultural psychology. *Distance Education, 34*(1), 129–136.

Clegg, C., & Walsh, S. (2004). Change management: Time for a change! *European Journal of Work and Organizational Psychology*, *13*, 217–239.

Cockburn, A. (2005). The anatomy of change: An insider's perspective. *International Journal of Leadership in Education*, *8*, 335–346. https://doi:10.1080/1360312050017065

Cohen, D., & Crabtree, B. (2006). *Qualitative research guidelines project*. Retrieved from: http://www.qualres.org/HomeSemi-3629.html

Cohen, L., Manion, L., & Morrison, K. (2000). *Research methods in education*. Routledge Falmer.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed.). Routledge.

Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education* (7th ed.). Routledge.

Collins. (n.d.). Cohort. *Collins Dictionaries Online* 2022. Retrieved January 15, 2022, from: https://www.collinsdictionary.com/dictionary/english

Collins. (2006). *Student's dictionary* (2nd ed.). HarperCollins.

Corbetta, P. (2003). *Social research theory, methods and techniques.* SAGE.

Corbin, J., & Strauss, A. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (3rd ed.). SAGE.

Cornford, T., & Smithson, S. (1996). *Project research in information systems. A student's guide*. Macmillan.

Coyne, I. (1997). Sampling in qualitative research. Purposeful and theoretical sampling; merging or clear boundaries? *Journal of Advance Nursing, 26*(3), 623–630.

Creswell, J. (1994). *Research design: Qualitative and quantitative approaches*. SAGE.

Creswell, J. (2008). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (3rd ed.). Pearson Education.

Creswell, J. (2009). *Research design: Qualitative, quantitative and mixed methods approaches* (3rd ed.). SAGE.

Creswell, J. (2012). *Educational research: Planning, conducting and evaluating quantitative and qualitative research* (4th ed.). Pearson.

Creswell, J. (2014). *Research design: Qualitative, quantitative and mixed methods approaches* (4th ed.). SAGE.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. SAGE.

Cummings, T., & Worley, C. (2015). *Organization development and change* (10th ed.). Cengage.

Curtis, S., Gesler, W., Smith, G., & Washburn, S. (2000). Approaches to sampling and case selection in qualitative research: Examples in the geography of health. *Social Science & Medicine*, *50*(7–8), 1001–14. http://dx.doi.org/10.1016/S0277–9536(99)00350–0

Darke, P., Shanks, P., & Broadbent, M. (1998). Successfully completing case study research: combining rigour, relevance and pragmatism. *Information Systems Journal, 8*, 273–289.

David, A. (2018). *Transforming higher education and research with the Internet of things*. Retrieved from: https://www.digitalistmag.com/iot/2018/03/13/transforming-higher-educationresearch-with-internet-of-things-05976196/

Davids, N., & Waghid, Y. (2020). Gender under-representation in teaching: A casualty of the feminisation of teaching? *South African Journal of High Education*, *34*(3), 1–12. http://dx.doi.org/10.20853/34–3–4045

Davis, E. (2011). *Teachers' experiences in the implementation of the technology education curriculum in one secondary school in the St George East district in Trinidad* (master's dissertation, The University of the West Indies). http://repositorioslatinoamericanos.uchile.cl/handle/2250/3015820

Dent, E., & Goldberg, S. (1999). Challenging resistance to change. *The Journal of Applied Behavioural Science*, *35*(1), 25–41.

Denzin, N. (1978). *The research act: A theoretical introduction to sociological methods* (2nd ed.). McGraw Hill.

Denzin, N., & Lincoln, Y. (2000). *Handbook of qualitative research* (2nd ed.). SAGE.

Denzin, N., & Lincoln, Y. (2003). *The landscape of qualitative research: Theories and issues*. SAGE.

Denzin, N., & Lincoln, Y. (2011). Introduction: Disciplining the practice of qualitative research. In N. Denzin & Y. Lincoln (Eds.), *The sage handbook of qualitative research* (4th ed., pp. 1–6). SAGE.

Department of Basic Education. (2011). *Curriculum News: Improving the quality of learning and teaching. Strengthening curriculum implementation from 2010 and beyond.* Pretoria: Department of Basic Education.

de Souza Barros, S., & Elia, M. (1998). *Physics teacher's attitudes: How do they affect the reality of the classroom and models for change?* Retrieved from: http://pluslucis.univie.ac.at/Archiv/ICPE/D2.html

Desplaces, D. (2005). A multilevel approach to individual readiness to change. *Journal of Behavioural and Applied Management*, *7*, 25–39.

Dewey, J. (2001). *Theory of experiential learning*. Western Collage.

Dick, W., & Carey, L. (1996). *The systematic design of instruction* (4th ed.). Harper Collins.

Dickey, M. (2005). Engaging by design: How engagement strategies in popular computer and video games can inform instructional design. *Educational Technology Research and Development, 53*, 67–83. https://doi.org/10.1007/BF02504866

Domegan, C., & Fleming, D. (2007). *Marketing research in Ireland* (3rd ed.). Gill MacMillan.

Downes, S. (2012). *Connectivism and connective knowledge. Essays on meaning and learning networks.* National Research Council.

Downes, S. (2014). The MOOC of one, *Stephen's Web*. Retrieved from: http://cck11.mooc.ca/

Du Plessis, P., & Mestry, R. (2019). Teachers for rural schools-a challenge for South Africa. *South African Journal of Education, 39*(2019)*, 1–9.

DuFour, R. (2002). The learning-centered principal. *Educational Leadership*, *59*(8), 12–15.

Durie, M. (2004, March). Exploring the interface between science and indigenous knowledge. *Paper presented at the 5th APEC Research and Development Leaders Forum.* Christchurch, New Zealand. Retrieved from: https://www.massey.ac.nz/documents/486/M_Durie_Exploring_the_interface_Between_Science_and_Indigenous_knowledge.pdf

Dwivedi, Y., Rana, N., Jeyaraj, A., Clement, M., & Williams, M. (2017). Re-examining unified theory of acceptance and use of technology: Towards a revised theoretical model. *Information System Frontiers, 21*(3)*, 719–734.

Eby, L., Adams, D., Russell, J., & Gaby, S. (2000). Perceptions of organizational readiness for change: Factors related to employees' reactions to the implementation of team-based selling. *Human Relations*, *53*, 419–442.

Eikeland, I., & Ohna, S. (2022) Differentiation in education: a configurative review. *Nordic Journal of Studies in Educational Policy*, *8*(3), 157–170. https://doi.org/10.1080/20020317.2022.2039351

Fabriz, S., Hansen, M., Heckmann, C., Mordel, J., Mendzheritskaya, J., Stehle, S., Schulze-Vorberg, L., Ulrich, I., & Horz, H. (2021). How a professional development programme for university teachers impacts their teaching-related self-efficacy, self-concept, and subjective knowledge. *Higher Education Research Development*, *40*(4), 738–752.

Fomunyam, K. (2019). Education and the fourth industrial revolution: Challenges and possibilities for engineering education. *International Journal of Mechanical Engineering and Technology, 10*(8), 271–284.

Frey, L., Botan, C., & Kreps, G. (2000). *Investigating communication: An introduction to research methods* (2nd ed.). Allyn and Bacon.

Fullan, M. (2001). Implementing change at the building level. In W. Owings & L. Kaplan (Eds.), *Critical and emerging issues in educational leadership.* Retrieved from: https://michaelfullan.ca/wp-content/uploads/2016/06/13396045300.pdf

Fullan, M. (2002). Change processes and strategies at the local level. *Elementary Journal, 85*(3), 391–421.

Fullan, M. (2007). *The new meaning of educational change* (4th ed.). Teachers College Press.

Gambari, A., & Yusuf, M. (2017). Relative effectiveness of computer-supported jigsaw II, STAD and TAI cooperative learning strategies on performance, attitude, and retention of secondary school students in physics. *Journal of Peer Learning*, *10*, 76–94.

Gast, I., Schildkamp, K., & van der Veen, J. T. (2017). Team-based professional development interventions in higher education: A systematic review. *Review of Educational Research*, *87*(4), 736–767.

Ghavifekr, S., & Rosdy, W. (2015). Teaching and learning with technology: Effectiveness of ICT integration in schools. *International Journal of Research in Education and Science, 1*(2), 175–191.

Gibbs, G. (2007). *Thematic coding and categorizing, Analyzing qualitative data*. SAGE. http://dx.doi.org/10.4135/9781849208574

Gist, M., & Mitchell, T. (1992). Self-efficacy: A theoretical analysis of its determinants and malleability. *Academy of Management Review*, *17*(2), 183–211.

Glaser, B. (1978). *Theoretical sensitivity*. Sociology Press.

Glickman, C. (1991). Pretending not to know what we know. *Educational Leadership*, *48*(8), 4–10.

Graham, C. (2004). Blended learning systems: Definition, current trends, and future directions, In C. Bonk & C. Graham (Eds.), *Handbook of blended learning: Global perspectives, local designs* (pp. 533–549). Pfeiffer.

Gray, A. (2016, January 19). The 10 skills you need to thrive in the fourth industrial revolution. *World Economic Forum*. Retrieved from: https://www.weforum.org/agenda/2016/01/the-10–skills-you-need-to-thrive-in-the-fourth-industrial-revolution/

Greeff, M. (2005). Information collection: Interviewing. In A. De Vos, H. Strydom, C. Fouche & C. Delport (Eds.), *Research at grass roots: For the social sciences and human service professions* (pp. 286–313). Van Schaik.

Grix, J., (2001). *Demystifying postgraduate research*. University of Birmingham University Press.

Guba, E. (1990). *The paradigm dialog*. SAGE.

Guba, E., & Lincoln, Y. (1994). Competing paradigms in qualitative research. In N. Denzin & Y. Lincoln (Eds.), *Handbook of qualitative research* (pp. 105–117). SAGE.

Gwata, M. (2019, August 05). To flourish in the fourth industrial revolution, we need to rethink these 3 things. *World Economic Forum*. Retrieved from: https://www.weforum.org/agenda/2019/08/fourth-industrial-revolution-education/https://www.education.gov.za/Programmes/EMIS/StatisticalPublications.aspx

Hall, G., & Hord, S. (2011). *Implementing change: Patterns, principles, and potholes*. Allyn and Bacon.

Hamilton, D. (2014). *Towards a theory of schooling*. Routledge.

Harasim, L. (2017). *Learning theory and online technologies* (2nd ed.). Routledge.

Hargreaves, A. (2003). *Teaching in the knowledge society: Education in the age of insecurity*. Open University Press.

Hashim, H. (2018). Application of technology in the digital era education. *International Journal of Research in Counseling and Education, 2,* 1–5. https://doi.org/10.24036/002za0002

Heinonen, N., Katajavuori, N., Murtonen, M., & Södervik, I.(2022). Short pedagogical training in supporting university teachers' professional vision: A comparison of prospective and current faculty teachers. *Instructional Science, 51*, 201–229.

Henning, E., Van Rensburg, W., & Smit, B. (2004). *Finding your way in qualitative research*. Van Schaik.

Hennink, M., Hutter, I., & Bailey, A. (2011). *Qualitative research methods*. SAGE.

Herlo, D. (2017). Connectivism, A new learning theory*?* In E. Soare, & C, Langa (Eds.), *Education facing contemporary world issues. Proceedings of the 7ᵗʰ International Conference Edu World 2016* Pitesti, Romania. (pp. 330–337). Retrieved from: https://www.europeanproceedings.com/book-series/EpSBS/books/vol23-edu-world-2016/

Higgins, T. (1996). Knowledge activation: Accessibility, applicability, and salience. In T. Higgins & A. Kruglanski (Eds.), *Social psychology: Handbook of basic principles* (pp. 133–168). Guilford Press.

Hinojo-Lucena, F., Aznar-Diaz, I., Caceres-Reche, M., & Romero-Rodriguez, J. (2019). '*Artificial intelligence in higher education: A bibliometric study on its impact in the scientific literature*'. *Education Sciences, 9*(1), 51. https://doi.org/10.3390/educsci9010051

Hitchcock, G., & Hughes, D. (1995). *Research and the teacher* (2ⁿᵈ ed.). Routledge.

Hoadley, U., & Jansen, J. (2009). *Curriculum: Organising knowledge for the classroom* (2ⁿᵈ ed.). Oxford University Press.

Hoadley, U., & Jansen, J. (2013). *Curriculum: Organising knowledge for the classroom* (3ʳᵈ ed.). Oxford University Press.

Holt, D., Armenakis, A., Field, H., & Harris, S. (2007). Readiness for organisational change: The systematic development of a scale. *The Journal of Applied Behaviorial Science*, *43*(2), 232–255.

Hoover, J., & Patton, J. (2005). *Components of curriculum implementation*. Retrieved from: http://www. Ptgmedia.pearsoncmg.com

Horan, N. (2020). *An investigation into the impact of inquiry-based learning on young learners' environmental awareness and agency in the local environment* (Master's dissertation, Marino Institute of Education, Dublin, Ireland). Retrieved from: http://www.tara.tcd.ie/handle/2262/95355

Huber, L. (2002). From general education to interdisciplinary studies. *Higher Education Policy*, *15*,19–31.

Hudson, L., & Ozanne, J. (1988). Alternative ways of seeking knowledge in consumer research. *Journal of Consumer Research*, *14*(4), 508–521.

Hussin, A. (2018). Education 4.0 made simple: Ideas for teaching. *International Journal of Education & Literacy Studies, 6*(3), 92–98.

Iredale, A. (2012) Down the rabbit-hole: Routinised practices, Dewey and teacher training in the lifelong learning sector. *Higher Education, Skills and Work-based Learning*, *2*(1), 54–62.

Jackson, R., Drummond, D., & Camara, S. (2007). What is qualitative research? *Qualitative Research Reports in Communication, 8*(1), 21–28.

Jansen, J. (1999). Setting the scene: historiographies of curriculum policy in South Africa. In J. Jansen & P. Christie (Eds.), *Changing curriculum: studies on outcomes-based education in South Africa* (pp. 3–18). Juta.

Jansen, J. (2002). Political symbolism as policy craft: Explaining non-reform in South African education after apartheid. *Journal of Education Policy*, *17*(2), 199– 215.

Jansen, J., & Taylor, N. (2003). *Educational change in South Africa 1994–2003: Case studies in large-scale education reform*. Retrieved from:

https://www.jet.org.za/resources/Jansen%20and%20Taylor_World%20Bank%20repo rt.pdf/view

Jenkins, J. (2002). General education in the University of Massachusetts Amherst: A new rationale. *Higher Education Policy, 15*, 45–54.

Jex, S., & Britt, T. (2008). *Organizational psychology: A scientist practitioner approach.* Wiley.

Johnson, K., Dempster, E., & Hugo, W. 2011. Exploring the recontextualisation of biology in the South African life sciences curriculum, 1996–2009. *Journal of education*, *52*, 27-58.

Johnson, D., & Johnson, R. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher, 38*(5), 365–379. https://doi.org/10.3102/0013189X09339057

Junid, N., Soh, T., Mahmud, S., & Iksan, Z. (2019). Science teacher's knowledge, understanding and readiness in dealing with the education transformation of the 4th industrial revolution. *International Journal of Innovation, Creativity and Change*, *7*(11), 102–119.

Kajornboon, A. (2005). *Using interviews as research instruments*. Retrieved from: http://www.culi.chula.ac.th/e-journal/bod/Annabel.pdf

Kamaruzaman, F., Hamid, R., Mutalib., A, & Rasul, M. (2019). Conceptual framework for the development of 4IR skills for engineering graduates. *Global Journal of Engineering Education*, *21*(1), 54–61.

Kaplan, A. (1964). *The conduct of inquiry: Methodology for behavioral science.* Chandler.

Kayembe, C., & Nel, D. (2019). Challenges and opportunities for education in the fourth industrial revolution. *African Journal of Public Affairs, 11*(3), 79–94.

Kearsley, G., & Shneiderman, B. (1998). Engagement theory: A framework for technology-based teaching and learning. *Educational Technology, 38*(5), 20–23.

Khalo, X. (2020). *Exploring information and communication technology integration in Life Sciences teaching in rural schools in South Africa*. Proceedings of EDULEARN20 Conference (pp. 8954–8961). https://doi.org/10.21125/edulearn.2020.0622

Khoza, S. (2013). Learning outcomes as understood by 'published research' facilitators at a South African university. *Mevlana International Journal of Education, 3*(2), 1–11.

Klein, H., & Meyers, M. (1999). A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS Quarterly, 23*(1), 67–94.

Klein, J. (1990). *Crossing boundaries: Knowledge, disciplinarities and interdisciplinarities.* The University Press.

Kogut, B., & Zander, U. (1996). What firms do? Coordination, identity, and learning. *Organization Science*, *7*, 502–518.

Kolb, D. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice-Hall.

Kondakci, Y., Beycioglu, K., Sincar, M., & Ugurlu, C. (2017). Readiness of teachers for change in schools. *International Journal of Leadership in Education*, *20*(2), 176–197.

Koopman, O. (2022). The fourth industrial revolution: Teachers' views on integrating digital technologies as a 21-century teaching strategy. *African Perspectives of Research in Teaching & Learning*, *6*(3), 59–73.

Koskei, K. (2015). Assessment of stakeholders' influence on curriculum development process in secondary schools in Kericho Country. *Journal of Humanities and Social Sciences, 20*(3), 79–87.

Kozlowski, S., & Klein, K. (2000). A multilevel approach to theory and research in organizations: Contextual, temporal, and emergent processes. In K. Klein & S. Kozlowski (Eds.), *Multilevel theory, research, and methods in organizations* (pp. 3–90). Jossey-Bass.

Kritsonis, A. (2005). Comparison of Change Theories. *International Journal of Scholarly Academic Intellectual Diversity*, *8*(1), 1–7.

Kuhn, T. (1962). *The structure of scientific revolutions.* Retrieved from:
http://www.sjsu.edu/people/annapurnc.pandey/courses/MSR122/sl/Thomas%20Kuhn.
pdf

Lacey, A., & Luff, D. (2009). *Qualitative data analysis*. The NIHR RDS for the East
Midlands: Yorkshire & the Humber. Retrieved from:
https://www.rdsyh.nihr.ac.uk/wpcontent/uploads/2013/05/9_Qualitative_Data_Analys
is_Revision_2009.pdf

Latham, B. (2007). *Sampling: What is it?* Retrieved from:
http://webpages.acs.ttu.edu/rlatham/Coursework/5377(Quant))/Sampling_Methodolog
y_Paper.pdf

Lee, M., Yun, J., Pyka, A., Won, D., Kodama, F., Schiuma, G., Park, H., Jeon, J., Park, K.,
Jung, K., Yan, M., Lee, S., & Zhoa, X. (2018). How to respond to the fourth industrial
revolution, or the second information technology revolution? Dynamic new
combinations between technology, market, and society through open innovation.
Journal of Open Innovation: Technology, Market and Complexity, *4*(21), 1–24.

Leedy, P., & Ormrod, J. (2001). *Practical research: Planning and design* (7th ed.). Merrill
Prentice Hall.

Lewin, K. (1947). Frontiers in group dynamics: Concept, method and reality in social
science; social equilibria and social change. *Human Relations*, *1*(1), 5–41.

Lincoln, Y., & Guba, E. (1985). *Naturalistic inquiry*. SAGE.

Locke, E. (1976). The nature and causes of job satisfaction. In M. Dunnette (Ed.), *Handbook
of industrial and organizational psychology* (pp. 1293–1349). Rand McNally.

Lynch, D., Smith, R., Provost, S., Yeigh, T., & Turner, D. (2017). The correlation between
'teacher readiness' and student learning improvement. *International Journal of
Innovation, Creativity and Change, 3*(1), 1–11.

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.

Kong, T. Yang & C. Tse (Eds.), *Emerging practices in scholarship of learning and teaching in a digital age.* (pp. 19–38). Springer.

Mack, L. (2010). The philosophical underpinnings of educational research. *Polyglossia, 19* (1), 5–11.

Maddock, L., & Maroun, W. (2018). Exploring the present state of South African education: Challenges and recommendations. *South African Journal of Education*, *32*(2), 192–214.

Magout, M. (2020). Theoretical Framework and Literature Review. In *A Reflexive Islamic Modernity*, 29-56.

Maharajh, L., Nkosi, T., & Mkhize, M. (2016). Teachers' experiences of the implementation of the Curriculum and Assessment Policy Statement (CAPS) in three primary schools in KwaZulu Natal. *Africa's Public Service Delivery and Performance Review*, *4*(3), 371–388.

Makaye, J. (2014). Curriculum implementation in Zimbabwe: Phases and passages. *Standard Global Journal of Educational Research, 1*(5), 96–102.

Maree, K. (Ed.). (2007). *First steps in research*. Van Schaik.

Marris, P. (1975). *Loss and change*. Anchor Press.

Marshall, C., & Rossman, G. (1999). *Designing qualitative research.* SAGE.

Marshall, M. (1996). Sampling for qualitative research. *Family Practice, 13*(6), 522–525.

Marwala, T. (2020). *Closing the gap: The fourth industrial revolution in Africa*. Macmillan.

Marzano, R. (2003). *What works in schools: Translating research into action.* Association for Supervision and Curriculum Development.

Maxwell, J. (1997). Designing a qualitative study. In L. Bickman & D. Rog (Eds.). *Handbook of applied social research methods.* SAGE.

Maxwell, N. (2003). Two great problems of learning. *Teaching in higher education*, *8*(1),129–134.

Mayer, R., Davis, J., & Schoorman, F. (1995). An integrative model of organizational trust. *Academy of Management Review*, *20*, 709–734.

Mc Millan, J., & Schumacher, S. (1993). *Research in education. A conceptual introduction*. (3rd ed.). Harper Collins.

McMillan, J., & Schumacher, S. (2001). *Research in education*: *A conceptual introduction* (5th ed.). Addison Wesley Longman.

McMillan, J., & Schumacher, S. (2010). *Research in education-Evidence-based inquiry*. (7th ed.). Pearson Education.

McPherson-Geyser, G., de Villiers, R., & Kavai, P. (2020). The use of experiential learning as a teaching strategy in Life Sciences. *International Journal of Instruction*, *13*(3), 877–894.

Menon, K., & Castrillon, G. (2019). Reimaging curricula for the fourth industrial revolution. *The Independent Journal of Teaching and Learning, 14*(2), 6–16.

Merriam, S. (1985). The case study in educational research: A review of selected literature. *Journal of Educational Thought*, *19*(3), 204-217.

Merriam, S. (1998). *Qualitative research and case study application in education.* Jossey-Bass.

Merriam, S. (2009). *Qualitative research: A guide to design and implementation* (3rd ed.). Jossey-Bass.

Merriam-Webster. (n.d.). Change. In *Merriam-Webster.com dictionary.* Retrieved January 15, 2022, from: https://www.merriam-webster.com/dictionary/dictionary

Miles, M., & Huberman, A. (1994). *Qualitative data analysis: An expanded source book* (2nd ed.). SAGE.

Miskon, S., Bandara, W., & Fielt, E. (2015). Applying the principles of interpretive field research: As example of an IS case study on shared services. *Asian Research Publishing Network Journal of Engineering and Applied Sciences, 10*(23), 18078–18086.

Mnguni, L. (2012). *The relationship between the grade 11 life sciences curriculum documents, HIV/AIDS knowledge and behavioural preferences* (Doctoral dissertation, University of Pretoria). https://repository.up.ac.za/handle/2263/23581

Mnguni, L. (2019). *Teaching life sciences in further education and training*. University of South Africa.

Molenda, M., Reigeluth, C., & Nelson, L. (2003). Instructional design. In L. Nadel (Ed.), *Encyclopedia of cognitive science* (Vol. 2, pp. 574–578). Nature Publishing.

Molla, E., & Muche, M. (2018). Impact of cooperative learning approaches on students' academic achievement and laboratory proficiency in biology subject in selected rural schools, Ethiopia. *Education Research International*, *2018*(2), 1–9. http://dx.doi.org/10.1155/2018/6202484

Moloi, T., & Marwala, T. (2020). *Artificial intelligence in economics and finance theories*. Springer.

Moloi, T., & Mhlanga, D. (2021). Key features of the fourth industrial revolution in South Africa's basic education system. *Journal of Management Information and Decision Sciences, 24*(5), 1–20.

Moore, K. (2000). *Classroom teaching skills* (5th ed.). McGraw Hill.

Morehouse, R. (2011). *Beginning interpretative inquiry: A step-by-step approach to research and evaluation*. Routledge.

Morris, P., & Adamson, B. (2010). *Curriculum, schooling and society in Hong Kong*. Hong Kong University Press.

Morse, J. (1991). Strategies for sampling. In J. Morse (Ed.), *Qualitative nursing research: A contemporary dialogue* (pp. 127–145). SAGE.

Morse, J., Barrett, M., Mayan, M., Olson, K., & Spiers, J. (2002). Verification strategies for establishing reliability and validity in qualitative research. *International Journal of Qualitative Methods*, *1*(2), 13–22. https://doi.org/10.1177/160940690200100202

Mostafa, J., Hashemi, S., Sosahabi, P., & Berahman, M. (2017). The role of ICT in learning-teaching process. *World Scientific News*, *72*(2017), 680–691.

Muijs, D., & Reynolds, D. (2018). *Effective teaching evidence and practice* (4th ed). SAGE.

Murgatrotd, S. (2020). *COVID-19 and online learning*. Retrieved from: https//doi.org/10.13140/RG.2.2.31132.85120

Nababan, T., Purba, S., & Siburian, P. (2020). *The challenge of being a teacher in industrial revolution 4.0.* Proceedings of the 5th Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2020) (pp. 219–223). http://dx.doi.org/10.2991/assehr.k201124.047

Naidoo, P. (2010). *Teachers' interpretation and implementation of the policy on indigenous knowledge in the science national curriculum statement* (Doctoral dissertation, University of KwaZulu-Natal). http://hdl.handle.net/10413/765

Ndlendle, S. (2019, July 16). Motshekga says basic education ready to tackle fourth industrial revolution. *Independent Online*. Retrieved from: https://www.iol.co.za/news/politics/motshekga-says-basic-education-ready-to-tackle-fourth-industrial-revolution-29325459

Ndlovu, E. (2012). *Interpretation and enactment by teachers of the interrelated of technology-society-environment and other themes of the technology curriculum* (Master's dissertation, University of Pretoria). http://hdl.handle.net/2263/36796

Neuman, W. (2000). *Social research methods: Qualitative and quantitative approaches* (4th ed.). Allyn and Bacon.

Ngulube, P., Mathipa, E., & Gumbo, M. (2015). Theoretical and conceptual framework in the social sciences, In E. Mathipa & M. Gumbo (Eds.), *Addressing research challenges: Making headway in developing researchers* (pp. 43–66). Mosala-MASEDI.

Niess, M., & Gillow-Wiles, H. (2017). Expanding teachers' technological pedagogical reasoning with a systems pedagogical approach. *Australasian Journal of Educational Technology*, *33*(3). https://doi.org/10.14742/ajet.3473

Nieuwenhuis, J. (2007). Qualitative research designs and data gathering techniques. In K. Maree (Ed.), *First steps in research*. Van Schaik.

Noor, S., Isa, F., & Mazhar, F. (2020). Online teaching practices during the COVID-19 pandemic. *Educational Process: International Journal*, *9*(3), 169–184.

Nowell, L., Norris, J., White, D., & Moules, N. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods*, *16*(1), 1–16. https://doi.org/10.1177/1609406917733847

Nuraidah, E., Nugroho, A., & Andini, N. (2021). *Exploring the implementation of English teacher's teaching strategies*. LEAD. https://doi.org/10.20884/1.lead.2021.1.1.4826

Nxumalo-Dlamini, N., & 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.

Nyagah, G. (2001). *Curriculum studies*. African Virtual University. http://creativecommons.org/licenses/by/2.5/

O'Sullivan, M. (2002). Reform implementation and the realities within which teachers work: A Namibian case study. *Compare, 32*(2), 219–237.

Obara, J., & Okoh, C. (2005). Instructional materials production: The need for improvisation and innovation. *Africa Journal of Education and Developmental Studies, 2*(1 & 2), 129–136.

Ödalen, J., Brommesson, D., Erlingsson, G., Schaffer, J., & Fogelgren, M. (2019). Teaching university teachers to become better teachers: The effects of pedagogical training courses at six swedish universities. *Higher Education Research Development*, *38*(2), 339–353.

Ofoha, D., Uchegbu, C., Anyika, B., & Nkemdirim, M. (2009). *A critical appraisal of the mode of implementation of Nigerian secondary school curriculum: Towards socio-economic empowerment of youth*. Education Research Network for West and Central Africa.

Ojo, O., & Adu, E. (2018). The effectiveness of information and communication technologies (ICTs) in teaching and learning in high schools in Eastern Cape province. *South African Journal of Education*, *38*(2), pp. 1–11.

Oke, A., & Fernandes, F. (2020). Innovations in teaching and learning: Exploring the perceptions of the education sector on the 4th industrial revolution (4IR). *Journal of Open Innovation: Technology, Market, and Complexity*, *6*(31). https://doi.org/10.3390/joitmc6020031

Okello, V., & Kagoire, M. (1996). *Makerere University Curriculum Studies Module*. Bezatel Design Studies.

Olic, S., & Adamov, A. (2018). The relationship between learning styles and students' chemistry achievement. *Macedonian Journal of Chemistry and Chemical Engineering*, *37*(1); 79–88. http://dx.doi.org/10.20450/mjcce.2018.1400

Olofu, M. (2003). *Introduction to the fundamentals of curriculum development*. Ushie Printing and Publishing.

Oluwatoyin, A., & Gabriel, M. (2018). Two innovative teaching strategies and academic performance of senior secondary school students in biology: Ekiti State experience. *American Journal of Educational Science*, *4*(4), 127–135.

Onwuegbuzie, A., Leech, N., & Collins, K. (2008). Interviewing the interpretive researcher: A method for addressing the crises of representation, legitimation, and praxis. *International Journal of Qualitative Methods*, *7*, 1–17.

Organisation for Economic Cooperation and Development. (2009). *Teaching and learning international survey. Creating effective teachingand learning*. OECD.

Orlich, D., Harder, R., Callahan, R., Trevisan, M., & Brown, A. (2010). *Teaching strategies: A guide of effective instruction* (9th ed.). Wadsworth Cengage Learning.

Ornstein, A., & Hunkins, F. (2004). *Curriculum: Foundations, principles and issues*. Pearson Educational Press.

Ornstein, A., & Hunkins, F. (2014). *Curriculum: Foundations, principles and issues* (6th ed.). Pearson Educational.

Ornstein, A., & Hunkins, F. (2018). *Curriculum: Foundations, principles and issues* (7th ed.). Pearson Educational.

Oxford University Press (n.d.a.). Change. *Oxford dictionaries online* 2022. Retrieved January 15, 2022, from: https://www.oed.com

Oxford University Press (n.d.b.). Fit for purpose. *Oxford dictionaries online* 2022. Retrieved January 15, 2022, from: https://www.oed.com

Ozer, O. (2004). *Constructivism in Piaget and Vygotsky*. Retrieved from: http://www.fountain magazine.com/Issue/detail/CONSTRUCTIVISM – in – Piaget – and – Vygotsky.html

Partnership for Twenty-First Century Skills. (2019). *Partnership for twenty-first century learning: Framework for twenty-first century learning definitions*. Retrieved from: http://static.battelleforkids.org/documents/p21/P21_Framework_DefinitionsBFK.pdf

Peach, M., Jimmieson, N., & White, K. (2005). Beliefs underlying employee readiness to support a building relocation: A theory of planned behaviour perspective. *Organization Development Journal*, *23*, 9–22.

Peters, M. (2017). Technological unemployment: Educating for the fourth industrial revolution. *Educational Philosophy and Theory*, *49*(1), 1–6.

Piekkari, R., Welch, C., & Paavilainen, E. (2009). The case study as disciplinary convention: Evidence from international business journals. *Organizational Research Methods*, *12*(3), 567–589. https://doi.org/10.1177/1094428108319905

Pillay, S. (2006). *Responses of science teacher educators to the curriculum change process in South Africa* (Doctoral dissertation, University of KwaZulu-Natal). http://hdl.handle.net/10413/2676

Polikoff, M., & Porter, A. (2014). Instructional alignment as a measure of teacher quality. *Educational Evaluation and Policy Analysis*, *36*(4), 399–416.

Pomeranz, K. (2000). *The great divergence: China, Europe, and the making of the modern world economy*. Princeton University Press.

Potter, D. (1991). Is George Mason a learning-centered university? *Invetio: Creative Thinking About Teaching and Learning*, *1*(1). http://www.doiiit.gmu.edu/Archives/feb98/potter.htm

Pritchard, A. (2009). *Ways of learning: Learning theories and learning styles in the classroom* (2nd ed.). David Fulton.

Rafferty, A., & Jimmieson, N. (2010). Team change climate: A group-level analysis of the relationships among change information and change participation, role stressors, and well-being. *European Journal of Work and Organizational Psychology*, *19*, 551–586.

Rafferty, A., & Simons, R. (2006). An examination of the antecedents of readiness for fine tuning and corporate transformation changes. *Journal of Business and Psychology*, *20*, 325–350.

Rao, V. (2010). *Curriculum development*. Saurabh.

Ravitch, D. (2007). *Edspeak: A glossary of education terms, phrases, buzzwords, and jargon*. Association for Supervision and Curriculum Development.

Razak, N., Alakrash, H., & Sahboun, Y. (2018). English language teachers' readiness for the application of technology towards fourth industrial revolution demands. *Asia-Pacific Journal of Information Technology and Multimedia, 7*(2–2), 89–98. https://www.researchgate.net/publication/346906587

Reaves, J. (2019). 21st-century skills and the fourth industrial revolution: A critical future role for online education. *International Journal on Innovations in Online Education, 3*(1). http://dx.doi.org/10.1615/IntJInnovOnlineEdu.2019029705

Reddy, V., Visser, M., Winnaar, L., Arends, F., Juan, A., Prinsloo, C., & Isdale, K. (2016). *TIMSS 2015: Highlights of mathematics and science achievement of grade 9 South African learners*. Human Sciences Research Council.

Riley, J. (2015). *Models of Change Management - Lewin's Force Field Model.* Retrieved from: http://www.tutor2u.net/business/reference/models-of-change-management-lewins-force-field-model

Ritchie, J., & Lewis, J. (2003). *Qualitative research practice: A guide for social science students and researchers.* SAGE.

Robbins, S. (2003). *Organizational behavior* (10th ed.). Prentice Hall.

Robson, C. (2002). *Real world research: A resource for social scientists and practitioner researchers* (2nd ed.). Blackwell.

Romy, A., Mohd Asri, A., Mohd Khalid, H., Normah, A., & Mohd Ali, S. (2019). Tahap pengetahuan dan tahap kesediaan guru pelatih Institut Pendidikan Guru Kampus Pendidikan Teknik (IPGKPT) terhadap Revolusi Industri 4.0 (IR 4.0) [The level of knowledge and the level of readiness of the teacher trainer at Technical Institute of Teacher Education Campus (IPGKPT) towards Industrial Revolution 4.0 (IR 4.0)]. *Jurnal Penyelidikan Teknokrat, II*(XXI), 27–37. Retrieved from: http://myjms.mohe.gov.my/index.php/jpt/article/view/8400

Rudhumbu, N. (2018). *A model for effective curriculum implementation in accredited private higher education institutions in Botswana* (Doctoral dissertation. University of South Africa). http://hdl.handle.net/10500/25436

Rusman, M. (2015). Curriculum implementation at elementary schools: A study on "best practices" done by elementary school teachers in planning, implementing, and evaluating the curriculum. *Journal of Education and Practice, 6*(21), 106–112.

Saleh, Z. (2019). *Artificial intelligence definition, ethics and standards*. Retrieved from: https://www.researchgate.net/publication/332548325_Artificial_Intelligence_Definition_Ethics_and_Standards

Sam, C., Owusu, K., & Anthony-Krueger, C. (2018). Effectiveness of 3E, 5E and conventional approaches of teaching on students' achievement in high school biology. *American Journal of Educational Research, 6*(1), 76–82.

Sansone, C., Morf, C., & Panter, A. (2003). *The SAGE handbook of methods in social psychology.* SAGE.

Saskatchewan Ministry of Education (1991). *Instructional approaches: A framework for professional practice.* Saskatchewan Education.

Saunders, M., Lewis, P., & Thornhill, A. (2016). *Research methods for business students*. Pearson Education.

Savenye, W., & Robinson, R. (2004). Qualitative research issues and methods. An introduction for educational technologists. *Qualitative Research Issues and Methods*, *39,* 1045–1071.

Sayed, Y., Singh, M., Bulgrin, E., Henry, M., Williams, D., Metcalfe, M., Pesambili, J., & Mindano, G. (2021). Teacher support, preparedness and resilience during times of crises and uncertainty: COVID-19 and education in the global south. *Journal of Education*, *84*, 125–154.

Schneiderman, B. (1994). *Education by engagement and construction: Can distance learning be better than face-to-face?* Retrieved from: http://www.hitl.washington.edu/scivw/EVE/distance.html

Schulze, E. (2019, January 17). *Everything you need to know about the fourth industrial revolution.* Retrieved from: https://www.cnbc.com/2019/01/16/fourth-industrial-revolution-explained-davos-2019

Schwab, K. (2015, December 12). *The fourth industrial revolution: What it means and how to respond*. Retrieved from: https://www.foreignaffairs.com/articles/2015–12–12/fourth-industrial-revolution

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

Schwab, K. (2017). *The fourth industrial revolution*. Crown.

Scott, D. (2002). General education for an integrative age. *Higher Education Policy*, *15*, 7–18.

Scott, S., & Dixon, K. (2008). The changing nature of higher education in the twenty-first: developments and trends. In S. Scott & K. Dixon (Eds.), *The globalised university: Trends and development in teaching and learning* (pp. 1–18). Black Swan Press.

Sekerka, L., Zolin, R., & Smith, J. (2009). Be careful what you ask for: How inquiry strategy influences readiness mode. *Organization Management Journal*, *6*, 106–122.

Shah, N. (2010). A study of the relationship between organizational justice and employee readiness for change. *Journal of Enterprise Information Management*, *24*, 224–236.

Sherif, Y., Brooks, D., & Mendenhall, M. (2020). *Teachers shoulder the burden: Improving support in crisis contexts*. Retrieved from: https://www.educationcannotwait.org/teachers-shoulder-the-burden-improving-support-in-crisis-contexts-opinion/

Siemens, G. (2004). Connectivism: A learning theory for the digital age. *International Journal of Instructional Technology and Distance Learning*. http://www.itdl.org/Journal/Jan_05/article01 .htm

Sim, J., & Sharp, K. (1998). A critical appraisal of the role of triangulation in nursing research. *International Journal of Nursing Studies*, *35*(1–2), 23–31. https://doi.org/10.1016/S0020–7489(98)00014–5

Singaram, S., & Mayer, C. (2022). The influence of the fourth industrial revolution on organisational culture: An empirical investigation. *Frontiers in Psychology*, *13*, 919157.

Singh, S. (1998). *Exploring teachers' beliefs about the nature of science and their relationship to classroom practices: A case-study with special reference to physical science teachers in the Empangeni-Richards Bay area* (Masters dissertation. University of KwaZulu-Natal). http://hdl.handle.net/10413/3233

Singh-Pillay, A., & Naidoo, J. (2020). Context matters: Science, technology and mathematics education lecturers' reflections on online teaching during the COVID-19 pandemic. *Journal of Baltic Science Education*, *19*(6a), 1125–1136.

Sinnema, C. (2010). *Monitoring and evaluating curriculum implementation: Final report to the ministry of education.* Ministry of Education, New Zealand.

Skaalvik, E., & Skaalvik, S. (2014). Teacher self-efficacy and perceived autonomy: Relations with teacher engagement, job satisfaction and emotional exhaustion. *Psychological Reports, 114*(1), 68–77. https://doi.org/10.2466/14.02.PR0.114k14w0

Smit, B. (2001). How primary school teachers experience education policy change in South Africa. *Perspectives in Education*, *19*(3), 67–84.

Smith, J. (1993). *After the demise of empiricism: The problem of judging social and educational inquiry.* Ablex.

Smith, P., & Ragan, T. (1999). *Instructional design*. Macmillan.

Spector, P. (1997). *Job satisfaction: Application, assessment, causes and consequences*. SAGE.

Speringer, M., & Schnelzer, J. (2019). *Differentiation of industry 4.0 models: The 4th industrial revolution from different regional perspectives in the global north and global south*. Retrieved from: http://dx.doi.org/10.13140/RG.2.2.35510.55363

Spooner, M., Flowers, C., Lambert, R., & Algozzine, B. (2008). Is more really better? Examining perceived benefits of an extended student teaching experience. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *81*(6), 263-270.

Statista. (2024). *Number of students in KwaZulu-Natal in South Africa 2022, by gender and race.* Retrieved from: https://www.statista.com/statistics/1352900/number-of-students-in-kwazulu-natal-in-south-africa-by-gender-and-grade/#:-text=In%202022

Strydom, H. (2005). Ethical aspects of research in the social sciences and human service professions. In A. De Vos (Ed.), *Research at grass roots: For the social sciences and human service professions,* (3rd ed., pp. 56–70). Van Schaik.

Subedi, S., Nayaju, S., Subedi, S., Shah, S., & Shah, J. (2020). Impact of e-learning during COVID-19 pandemic among nursing students and teachers of Nepal. *International Journal of Science and Healthcare Research*, *5*(3), 68–76.

Taba, H. (1962). *Curriculum development: Theory and practice*. Harcourt Brace and World.

Tadessa, W., & Meaza, F. (2007). Assessment on problems of the new pre-service teachers training program in Jimma University. *Ethiopian Journal of Education and Sciences*, *2*(2), 63–72.

Teddlie, C. (2007). Mixed methods sampling: A typology with examples. *Journal of Mixed Methods Research*, *1*(1), 77–100.

Terre Blanche, M., Durrheim, K., & Painter, D. (Eds.). (2006). *Research in practice* (2nd ed.). University of Cape Town Press.

Terry, D., & Callan, V. (1997). Employee adjustment to large-scale organisational change. *Australian Psychologist*, *32*, 203–210.

Thanh, N., & Thanh, T. (2015). The interconnection between interpretivist paradigm and qualitative methods in education. *American Journal of Educational Science, 1*(2), 24–27.

Thomas, P. (2010). *Towards developing a web-based blended learning environment at the University of Botswana* (Doctoral thesis, University of South Africa). http://hdl.handle.net/10500/4245

Tomlinson, C. (2014). *The differentiated classroom: Responding to the needs of all learners* (2nd ed.). Association for Supervision and Curriculum Development.

Tomlinson, C. (2017). *How to differentiate instruction in academically diverse classrooms* (3rd ed.). Association for Supervision and Curriculum Development.

Tschannen-Moran, M. (2001). Collaboration and the need for trust. *Journal of Educational Administration*, *39*, 308–331.

Tschannen-Moran, M., Hoy, A., & Hoy, W. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research*, *68*(2), 202–248.

Tubic, T. (2003). Socijalno-kognitivni čionioci stilova učenja [Socio-cognitive learners of learning styles]. *Norma*, *9*(2–3), 241–251.

Tymon, A. (2013). The student perspective on employability. *Studies in Higher Education*, *38*(6), 841–856.

United Nations Educational, Scientific and Cultural Organisation, United Nations International Children's Emergency Fund, & World Bank. (2020). *What have we learnt? Overview of findings from a survey of ministries of education on national*

responses to COVID-19. Retrieved from: https://tcg.uis.unesco.org/wp-content/uploads/sites/4/2020/10/National-Education-Responses-to-COVID-19–WEB-final_EN.pdf

United Nations Educational, Scientific and Cultural Organisation. (2020). *Education in a post COVID world: Nine ideas for public action*. Retrieved from: https://en.unesco.org/sites/default/files/education_in_a_post-covid_world-nine_ideas_for_public_action.pdf

United Nations. (2020). *Everyone included: Social impact of COVID-19*. Retrieved from: https://www.un.org/development/desa/dspd/

Van de Ven, A., & Poole, M. (1995). Explaining development and change in organisations. *Academy of Management Review*, *20*(3), 510–540.

van den Akker, J., de Boer, W., Folmer, E., Kuiper, W., Letschert, J., Nieveen, N., & Thijs, A. (2009). *Curriculum in Development*. Axis Media Ontwerpers.

van Dyk, H., & White, C. (2019). Theory and practice of the quintile ranking of schools in South Africa: A financial management perspective. *South African Journal of Education*, *39*(1), s1–s9. https://dx.doi.org/10.15700/saje.v39ns1a1820

van Manen, M. (1977). Linking ways of knowing with ways of being practical. *Curriculum inquiry, 6*(3)*,* 205–228.

Van Rooy, W. (2012). Using information and communication technology (ICT) to the maximum: Learning and teaching Biology with limited digital technologies. *Research in Science & Technological Education*, *30*(1), 65–80.

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

Viennet, R., & Pont, B. (2017). *Education policy implementation: A literature review and proposed framework.* OECD Publishing.

Vilppu, H., Södervik, I., Postareff, L., & Murttonen, M. (2019). The effect of short online pedagogical training on university teachers' interpretations of teaching-learning situations. *Instructional Science*, *47*, 679–709.

Wahyuni, D. (2012). The research design maze: understanding paradigms, cases, methods and methodologies. *Journal of Applied Management Accounting Research, 10*(1), 69–80. Retrieved from: https://ssrn.com/abstract=2103082

Walsham, G. (1995). Interpretive case studies in IS research: Nature and method. *European Journal of Information Systems, 4*(2), 74–81.

Wanberg, C., & Banas, J. (2000). Predictors and outcomes of openness to changes in a reorganizing workplace. *Journal of Applied Psychology*, *85*, 132–142.

Wassenaar, D. (2006). Ethical issues in social science research. In M. Terre Blanche, K. Durrheim & D. Painter (Eds.), *Research in practice: Applied methods for social sciences* (2ⁿᵈ ed., pp. 60–79). University of Cape Town Press.

Waugh, R., & Punch, K. (1987). Teacher receptive to systemwide change in the implementation stage. *Review of Educational Research*. *57*(3), 237–252.

Webber-Youngman, R. (2017). Life skills needed for the 4ᵗʰ industrial revolution. *The Journal of Southern African Institute of Mining and Metallurgy, 117*(4), iv–v.

Wells, G. (2007). Semiotic mediation, dialogue and the construction of knowledge. *Human Development*, *50*(5), 244 – 274.

Wesch, M. (2008). *A vision of students today & what teachers must do*. Retrieved from: http://blogs.britannica.com/2008/10/a-vision-of-students-today-what-teachers-mustdo/

Wesonga, F., & Aurah, C. (2019). Influence of teachers' instructional strategies and students' learning styles on academic achievement in Kenyan high school physics. *European Journal of Education Studies, 6*(8), 190–202.

Wheatley, G. (1995). Problem solving from a constructivist perspective. In D. Lavorie (Ed.), *Towards a cognitive-science perspective for scientific problem solving: A monograph of the national association for research in science teaching, 6,* (pp. 1–12). Ag Press.

Wiles, J., & Bondi, J. (2014). *Curriculum development: A guide to practice* (9ᵗʰ ed.). Pearson.

Willis, M., & Hodson, V. (1999). *Discover your child's learning style*. Prima.

Wills, G., & Bohmer, B. (2023). *Male managers, female teachers: The South African case of gender imbalances in school leadership and management*. Research on Socioeconomic Policy.

Wongwanich, S., Piromsombat, C., Khaikleng, P., & Sriklaub, K. (2015). Policy delivery strategies for education reform: A formative research and development. *Procedia-Social and Behavioral Sciences*, *171*(2015), 1365–1372.

World Economic Forum. (2016, January). *The future of jobs: Employment, skills and workforce strategy for the fourth industrial revolution*. Retrieved from: http://www3.weforum.org/docs/WEF_Future_of_Jobs

World Economic Forum. (2020, January 14). *Schools of the future: Defining new models of education for the fourth industrial revolution*. Retrieved from: https://www.weforum.org/reports/schools-of-the-future-defining-new-models-of-education-for-the-fourth-industrial-revolution

Xing, B., & Marwala, T. (2017). Implications of the fourth industrial age for higher education. *The Thinker Issue*, *73*, 10-15. Retrieved from: https://ssrn.com/abstract=3225331

Yang, X. (2013). Research on high school students' everyday life in the new curriculum reforms implementation progress in China. *Creative Education*, *4*, 93–99.

Yin, R. (1994). *Case study research: Design and methods* (2nd ed.). SAGE.

Yin, R. (2003). *Case study research: Design and methods* (3rd ed.). SAGE.

Yin, R. (2009). *Case study research: Design and methods* (4th ed.). SAGE.

Zainal, Z. (2007). Case study as a research method. *Jurnal Kemanusiaan, 5*(1), 1–6.

Zelik, M., Schau, C., Mattern, N., Hall, S., Teague, K., & Bisard, W. (1997). Conceptual astronomy: A novel model for teaching postsecondary science courses. *American Association of Physics Teachers*, *65*(10), 987–996.

Zhang, J. (2021). Integrative Analytics for Technological Pedagogical Content Knowledge. *Complexity, 2021*, 1-10.

Zhong, Q. (2006). Curriculum reform in China: Challenges and reflections. *Frontiers of Education in China, 1*(3), 370–382.

APPENDICES

APPENDIX A: UNIVERSITY ETHICAL CLEARANCE CERTIFICATE

UNISA | university of south africa

UNISA COLLEGE OF EDUCATION ETHICS REVIEW COMMITTEE

Date: 2021/07/07

Ref: **2021/07/07/10055959/17/AM**
Name: Mr MG Mc Knight
Student No.: 10055959

Dear Mr MG Mc Knight

Decision: Ethics Approval from 2021/07/07 to 2026/07/07

Researcher(s): Name: Mr MG Mc Knight
E-mail address: mcknim@unisa.ac.za
Telephone: 0794945231

Supervisor(s): Name: Prof L. Mnguni
E-mail address: lindelani.mnguni@wits.ac.za
Telephone: 0815144849

Title of research:

The Development of a Framework for Enhancing In – Service Life Sciences Teachers' Readiness to Adopt Fourth Industrial Revolution (4IR) – Based Instructional Strategies.

Qualification: PhD Curriculum Studies

Thank you for the application for research ethics clearance by the UNISA College of Education Ethics Review Committee for the above mentioned research. Ethics approval is granted for the period 2021/07/07 to 2026/07/07.

The **low risk** application was reviewed by the Ethics Review Committee on 2021/07/07 in compliance with the UNISA Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.

The proposed research may now commence with the provisions that:
1. The researcher will ensure that the research project adheres to the relevant guidelines set out in the Unisa Covid-19 position statement on research ethics attached.
2. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

3. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the UNISA College of Education Ethics Review Committee.

4. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.

5. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing.

6. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.

7. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.

8. No field work activities may continue after the expiry date **2026/07/07**. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

The reference number **2021/07/07/10055959/17/AM** should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.

Kind regards,

Prof AT Motlhabane
CHAIRPERSON: CEDU RERC
motlhat@unisa.ac.za

Prof PM Sebate
EXECUTIVE DEAN
Sebatpm@unisa.ac.za

Approved - decision template – updated 16 Feb 2017

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

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APPENDIX B: LETTER TO THE PRINCIPAL

UNISA
university
of south africa

Date: _____

Dear Sir/Madam

My name is Marcell Mc Knight, a lecturer in the Department of Science and Technology Education. I am currently conducting research under the supervision of Professor L. E. Mnguni, the Assistant Dean for Teaching and Learning (University of Witwatersrand) towards a PhD at the University of South Africa. I wish to request your permission to approach prospective participants at your school for a study entitled:

The Development of a Framework for Enhancing In–Service Life Sciences Teachers' Readiness to Adopt Fourth Industrial Revolution (4IR)-Based instructional strategies.

The Republic of South Africa stands on the precipice of educational reform, emanating from the impact the 4IR will have on education. The study aims to develop a framework which will enhance the readiness of in–service Life Sciences teachers to adopt 4IR-based instructional strategies. Permission to conduct this study has been granted by the College of Education Research Ethics Review Committee, University of South Africa (2021/07/07/10055959/17/AM).

In developing the above framework, the study will entail determining the readiness of in–service Life Sciences teachers to adopt 4IR-based instructional strategies. To do so data will be collected from an open-ended questionnaire, the analysis of the participants' lesson plans and semi–structured interviews.

The benefits of this study are that it will contribute to an understanding of in–service Life Sciences teachers' readiness to adopt 4IR-based instructional strategies. An understanding which could be utilised to inform decisions made by policymakers within the DBE. These decisions are important as teachers will be practising in a changing environment which by its very nature will demand them to face challenges inherent in a space of uncertainty. They will be compelled to make changes to their current teaching practices to successfully attain the vision of the new intended curriculum. The understanding could also assist teacher training

institutions in the planning of their programmes. The framework may also generate some solutions to address the Republic of South Africa's wavering position in terms of global Science standards.

There are no potential risks involved with this research. There will be no reimbursement or any incentives for participating in this research. The teachers' participation in this study is voluntary. Teachers may refuse to participate or withdraw from the study at any time with no negative consequences. Confidentiality and anonymity of records will be maintained by the College of Education, University of South Africa.

Upon completion of the research, the participants will be invited to a presentation of the findings. An electronic summary of the findings will also be made available to the participants at their request.

Yours sincerely

_____

Marcell Mc Knight

Response of Principal:

I……………………………………………………………… (full name of principal) hereby confirm that I understand the contents of this document, and the nature of the research and I grant the researcher permission to distribute/conduct the relevant data collection instruments among/to the Life Sciences teachers.

……………………………………   …………………………

Signature of Principal   Date

APPENDIX C: EXAMPLES OF PERMISSION TO APPROACH PROSPECTIVE PARTICIPANTS AT SCHOOLS

Response of Principal:

I..... ██ (full names of principal) hereby confirm that I understand the contents of this document, the nature of the research and I grant the researcher permission to distribute/conduct the relevant data collection instruments among/to the Life Sciences teachers.

.................███████........ .   ...██████████.........

Signature of Principal   Date

KWAZULU NATAL
DEPARTMENT OF EDUCATION
███████████████████████
EMAIL : ███████████████

Response of Principal:

I..... ████████████████████████████████ (full names of principal) hereby confirm that I understand the contents of this document, the nature of the research and I grant the researcher permission to distribute/conduct the relevant data collection instruments among/to the Life Sciences teachers.

...........████████............   ....████████...........

Signature of Principal   Date

███████ ECONDARY SCHOOL
███████████████
Durban, 4037
P.O. Box ██████████████████
Tel : ███████████████

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APPENDIX D: PARTICIPANT INFORMATION SHEET AND INFORMED CONSENT LETTER

Title: The Development of a Framework for Enhancing In–Service Life Sciences Teachers' Readiness to Adopt Fourth Industrial Revolution (4IR) – Based instructional strategies.

Dear Prospective Participant

My name is Marcell Mc Knight, and I am conducting research under the supervision of Professor L. E. Mnguni, the Assistant Dean for Teaching and Learning (University of Witwatersrand) towards a PhD at the University of South Africa. We are inviting you to participate in a study entitled:

The Development of a Framework for Enhancing In–Service Life Sciences Teachers' Readiness to Adopt Fourth Industrial Revolution (4IR)-Based instructional strategies.

WHAT IS THE PURPOSE OF THE STUDY?

This study is expected to collect important information that could assist me in developing a framework which would enhance the readiness of in-service Life Sciences teachers' adoption of 4IR-based instructional strategies. The Republic of South Africa stands on the precipice of educational reform, emanating from the impact the Fourth Industrial Revolution (4IR) will have on education.

WHY AM I BEING INVITED TO PARTICIPATE?

You are invited because you are a Life Sciences teacher currently implementing the Curriculum Assessment Policy Statement for Life Sciences. I obtained your contact details from your principal. The approximate number of participants is ten Life Sciences teachers.

WHAT IS THE NATURE OF MY PARTICIPATION IN THIS STUDY?

The study involves the use of a questionnaire, a lesson plan, classroom observations and semi-structured interviews. The questionnaire will take approximately 30 to 40 minutes to complete

while 20 to 30 minutes will be required to conduct the semi-structured interview. Participants will respond to both closed and open-ended questions.

CAN I WITHDRAW FROM THIS STUDY EVEN AFTER HAVING AGREED TO PARTICIPATE?

Participating in this study is voluntary and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and without giving a reason.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

Benefits to you include, the study creating an awareness of your instructional strategies and exposing you to current discourses on the Fourth Industrial Revolution and its possible influence on education. Participation in the study might prepare you for the envisaged curriculum reform relevant to instructional strategies.

ARE THERE ANY NEGATIVE CONSEQUENCES FOR ME IF I PARTICIPATE IN THE RESEARCH PROJECT?

There are no negative consequences if you decide to participate in the research.

WILL THE INFORMATION THAT I CONVEY TO THE RESEARCHER AND MY IDENTITY BE KEPT CONFIDENTIAL?

Your name will not be recorded anywhere, and no one will be able to connect you to the answers you give. Your answers will be given a code number or a pseudonym and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings.

HOW WILL THE RESEARCHER(S) PROTECT THE SECURITY OF DATA?

Hard copies of your answers will be stored by the researcher for five years in a locked cupboard/filing cabinet at the College of Education, Unisa for future research or academic purposes. Electronic information will be stored on a password-protected computer. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable. Hard copies will be shredded, and electronic copies will be permanently deleted from the hard drive of the computer using a relevant software program.

WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?

The participants will not receive any payment or incentives for participating in this research.

HAS THE STUDY RECEIVED ETHICS APPROVAL?

This study has received written approval from the Research Ethics Review Committee of the College of Education, University of South Africa. A copy of the approval letter can be obtained from the researcher if you so wish.

HOW WILL I BE INFORMED OF THE FINDINGS/RESULTS OF THE RESEARCH?

If you would like to be informed of the final research findings, please contact Marcell Mc Knight at 0794945231 or email mcknim@unisa.ac.za... Should you require any further information or want to contact the researcher about any aspect of this study you can use the above contact details. Should you have concerns about how the research has been conducted, you may contact Professor L. E. Mnguni at 011 7172764 or lindelani.mnguni@wits.ac.za.

Thank you for taking the time to read this information sheet and for participating in this study.

Thank you.

_____

Marcell Mc Knight

CONSENT TO PARTICIPATE IN THIS STUDY (Return slip)

I, _____ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits, and anticipated inconvenience of participation.

- I have read (or had explained to me) and understood the study as explained in the information sheet.
- I have had sufficient opportunities to ask questions and am prepared to participate in the study.
- I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).
- I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.
- I agree with the recording of the semi-structured interview.
- I have received a signed copy of the informed consent agreement.

Participant Name & Surname (please print)

_____

_____   _____

Participant signature   Date

Researcher's Name & Surname (please print)

_____

_____   _____

Researcher's signature   Date

APPENDIX E: EXAMPLE OF INFORMED CONSENT RETURN SLIP

CONSENT TO PARTICIPATE IN THIS STUDY (Return slip)

I, ▮▮▮▮▮▮▮▮▮▮▮▮▮▮▮ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits, and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.

I agree to the recording of the semi – structured interview.

I have received a signed copy of the informed consent agreement.

Participant Name & Surname (please print)

_____   _____
Participant Signature   Date

Researcher's Name & Surname (please print)

M. MCKNIGHT.
_____   _____
Researcher's signature   Date

APPENDIX F: COVER LETTER FOR OPEN-ENDED QUESTIONNAIRE

Dear Participant

This open-ended questionnaire forms part of my research entitled: The Development of a Framework for Enhancing In–Service Life Sciences Teachers' Readiness to Adopt Fourth Industrial Revolution (4IR)-Based instructional strategies. You have been selected by a purposive sampling strategy from the population of teachers. Hence, I invite you to take part in this activity.

This study aims to develop a framework for enhancing in–service Life Sciences teachers' readiness to adopt fourth industrial revolution (4IR)-based instructional strategies. The findings of the study may benefit participants regarding the awareness of 4IR-based instructional strategies.

You are kindly requested to complete this open-ended questionnaire, as honestly and frankly as possible and according to your personal views and experience. No foreseeable risks are associated with the completion of the open-ended questionnaire which is for research purposes only. The open-ended questionnaire will take approximately 45 minutes to complete.

You are not required to indicate your name or organisation and your anonymity will be ensured; however, an indication of your age, gender, occupation position etcetera will contribute to a more comprehensive analysis. All information obtained from this open-ended questionnaire will be used for research purposes only and will remain confidential. Your participation is voluntary, and you have the right to omit any question if so desired, or to withdraw from answering without penalty at any stage. After the completion of the study, an electronic summary of the findings of the research will be made available to you upon request.

 The administering of this open-ended questionnaire is in line with the ethical aspects of research as permission to conduct this study has been granted by the College of Education Research Ethics Review Committee, University of South Africa (2021/07/07/10055959/17/AM).

If you have any research-related enquiries, they can be addressed directly to me or my supervisor. My contact details are 079445231, e-mail: mcknim@unisa.ac.za and my supervisor can be reached at 011 7172764, e-mail: lindelani.mnguni@wits.ac.za.

APPENDIX G: OPEN-ENDED QUESTIONNAIRE

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Instructions for completing the questionnaire:

- This questionnaire consists of 3 Sections. Section One, Section Two and Section Three
- You are kindly requested to complete all Sections of the questionnaire.
- Please answer all questions as honestly and openly as possible according to your personal views and experience
- All responses to the questionnaire are strictly confidential and are for research purposes only. Pseudonyms will be used if a need to refer arises.
- If you experience any difficulties with the teacher reflection instrument, please contact, Marcell Mc Knight, at 0794945231.

SECTION ONE: TEACHER BIOGRAPHICAL DETAILS

Indicate with an X in the appropriate option.

1. Gender:

Male	Female	Other

2. Nationality:

South African	Other (Indicate):

3. Race:

Black	White	Indian	Coloured	Other

4. Age Group:

20 – 30yrs	31 – 40yrs	41 – 50yrs	51 – 60yrs	+ 60yrs

5. Teaching Experience:

1 – 5yrs	6 – 10yrs	11 – 15yrs	16 – 20yrs	21 – 25yrs	+ 25yrs

6. List your teaching qualifications.

Degree/Diploma	Institution (in full)	Fulltime or part-time	Date Obtained

7. Was instructional strategies/Methods/Tools covered in your qualifications?

Yes	No

8. Are there regular meetings/workshops for Life Sciences conducted by the Department of Education for all the grades (10 -12) in the F.E.T. band?

Yes	No

9. If no, which grades do not have regular meetings/workshops?

_____

_____

10. Do you or your school belong to any professional organizations or subscribe to magazines/ journals related to the teaching of Life Sciences?

Yes	No

11. If yes, please provide details of such professional organizations or magazines/journals.

_____

_____

_____

SECTION TWO: THE FOURTH INDUSTRIAL REVOLUTION

PART A:

The following table is concerned with the characteristics of Education in the 4th Industrial Revolution. Please indicate if you agree with, disagree with, or are uncertain about each statement in the table with an X in the appropriate column. The following key applies to the table:

A	AGREE
DA	DISAGREE
UN	UNCERTAIN

Table 1: Education in the Industrial Revolution Education

Content		A	UN	DA
NO.	**STATEMENTS**	**A**	**UN**	**DA**
1.	Emphasis on building awareness concerned with the wider world, sustainability and playing an active role in the global community			
2.	Develops skills necessary for innovation, including complex problem-solving, analytical thinking, creativity and systems analysis			
3.	Grounded in creating digital skills, including programming, digital responsibility, and the use of technology			
4.	Concentrates on interpersonal emotional intelligence, including empathy, cooperation, negotiation, leadership, and social awareness			
Learning Experiences				
5.	Learning is standardised in its delivery			
6.	Learning caters to the diverse individual needs of each learner			
7.	Everyone has access to learning and is therefore inclusive			
8.	Learning is process-based			
9.	Learning necessitates peer collaboration and more closely reflecting the future of work			
10.	Learning is a system where learning and skilling decrease over one's lifespan			
11.	Learning involves project- and problem-based content delivery			
12.	Learning is limited to those with access to school buildings			

13.	Learning is adaptable enough to empower each learner to improve at their own pace			
14.	Learning involves everyone constantly expanding on existing skills and securing new ones based on their individual needs			

PART B: INTENDED FOURTH INDUSTRIAL REVOLUTION INSTRUCTIONAL STRATEGIES

The following table is concerned with the instructional strategies you intend to adopt in the 4th Industrial Revolution. Please indicate with an X in the column alongside the Instructional Strategy. Use the space provided to justify/support your choice.

Table 2: instructional strategies

Types of instructional strategies	Place X
Direct Instruction	
Lecture	
Explicit Teaching	
Drill and Practice	
Compare and Contrast	
Demonstrations	
Guided and Shared – Reading, Listening, Viewing, Thinking	
Indirect Instruction	
Problem-Solving	
Case Studies	
Inquiry	

Reflective Discussion	
Writing to Inform	
Concept Formation	
Concept Mapping	
Interactive Instruction	
Debates	
Role Playing	
Panels	
Brainstorming	
Peer Partner Learning	
Discussion	
Laboratory Groups	
Cooperative Learning	
Jigsaw	
Problem-Solving	
Structured Controversy	

Tutorial Groups	
Interviewing	
Conferencing	
Experiential Learning	
Field Trips	
Narratives	
Conducting Experiments	
Simulations	
Games	
Storytelling	
Field Observations	
Role - Playing	
Synectics (creative thinking to problem solve)	
Independent Study	
Essays	
Computer Assisted Instruction	

Journals	
Reports	
Learning Activity Packages	
Correspondence Lessons	
Learning Contracts	
Homework	
Research Projects	
Assigned Questions	
Learning Centers	

SECTION THREE: OPEN-ENDED QUESTIONS:

1. Do you think the needs of society influence Education? If yes, please explain.

   _____

   _____

   _____

   _____

   _____

2. What is your general understanding of the 4IR?

   _____

   _____

   _____

   _____

   _____

   _____

3. What is your understanding of the term "instructional strategies"?

_____

_____

_____

_____

_____

_____

4. Do you think the 4IR will influence your teaching practice? If yes, please explain.

_____

_____

_____

_____

_____

5. If you think the 4IR will influence your teaching practice (question 4)? Do you think this influence is necessary and welcomed?

_____

_____

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_____

_____

6. Do you think you are ready to adapt to the influence of the 4IR based on the explanation from question 4?

_____

_____

_____

_____

_____

7. What materials/resources/equipment do you use when teaching?

_____

_____

_____

_____

_____

8. Have there been any curriculum reforms in the past that have influenced your teaching practice?

_____

_____

_____

_____

9. If yes, briefly describe how it influenced your teaching practice.

_____

_____

_____

_____

_____

10. Do you think you were prepared for this influence from question 9? Please explain your response.

_____

_____

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_____

_____

11. When attending Departmental meetings/workshops related to the curriculum, is the 4IR discussed?

_____

_____

_____

_____

_____

APPENDIX H: SEMI-STRUCTURED INTERVIEW SCHEDULE

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<u>Interview Questions for Participants:</u>

1. What is your understanding of the 4IR? Can you please explain further?
2. What skills do you think individuals will need to acquire for the 4IR? Can you please explain further or justify these skills?
3. Do you think the 4IR will influence education? If yes, can you please elaborate on your response? or justify and reasons for it?
4. Do you have any instructional strategies for the 4IR? If yes, can you identify them? Can you please explain why you have chosen the instructional strategies you have identified?
5. When faced with change how do you normally react to it? Why do say this?
6. Do you think the 4IR will influence your instructional strategies? If yes, how do you feel about this? How do you think it will influence your instructional strategies?

If the response is Yes to the previous question the following questions are asked:

7. Do you think the influence of the 4IR on the instructional strategies you identified is appropriate? What do you base your response on?
8. Who do you think will support you regarding the influence the 4IR will have on your instructional strategies? Can you please tell me more?
9. Do you think you will be able to handle the influence you identified the 4IR will have on your instructional strategies successfully? Can you please supply a reason/s for your response?
10. Do you think you will benefit from the influence you identified the 4IR will have on your instructional strategies? Can you please explain further?
11. Do you think that technology will improve your performance in the 4IR? Can you please explain further?

12. Do you think you have the necessary skills to use technology? Can you please explain further?

13. Are you normally influenced by others to adopt new ways are doing things? Can you please tell me more?

14. Do you think that your school has the technological infrastructure to support a technological way of doing things? Can you please explain your response?

APPENDIX I: LESSON PLAN TEMPLATE

Teacher:		Grade:	
Date:		Venue:	
Duration:		Term:	
Strand:		Topic: Content:	

Specific Aims: (Tick the appropriate aim)	Specific Aim 1: Knowing Life Sciences	Specific Aim 2: Investigating Phenomena in Life Science	Specific Aim 3: Appreciating and Understanding the History, Importance and Applications of Life Sciences in Society	
Prior Knowledge:				

Teacher activities	Learner activities	Resources		Written task or activity
		Chalkboard		
		Charts		
		Posters		
		Magazines		
		Newspaper		
		Video		
		DVD		
		Worksheet		
		Learners		
		Other (list below)		

255

		Enrichment:		
		Homework:		
		Teacher reflection:		

Additional Notes:

_____

_____

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APPENDIX J: LESSON PLAN ANALYSIS SCHEDULE

Lesson Plan Information

Participant	
Lesson Topic	
Lesson specific aims	
Duration	
Prior Knowledge	

Summary of components of the lesson plan

Teacher activities	
Learner activities	

Resources	258
Written task or activity	
Enrichment	
Homework	
Teacher reflection	

Lesson Plan Analysis Items

Item	Yes	No	Comment
1. Teacher activities indicate a teacher-centred approach.			

2. Learner activities encourage learner participation.			
3. The resources incorporate technology.			
4. Is there an over-reliance on any type of resource?			
5. Does the lesson plan do the following:			
a) Build awareness of the wider world, sustainability and play an active role in the global community.			
b) Develop skills necessary for innovation, including complex problem-solving, analytical thinking, creativity and systems analysis.			
c) Develop digital skills, including programming, digital responsibility, and the use of technology.			
d) Develop interpersonal emotional intelligence, including empathy, cooperation, negotiation, leadership, and social awareness.			
e) Cater to the diverse individual needs of each learner.			
f) Encourage inclusivity.			

g) Encourage peer collaboration and more closely reflect the future of work.			
h) Empowered each learner to improve at their own pace.			
i) Expanded on existing skills and secured new ones based on learner's individual needs.			

APPENDIX K: TURNITIN REPORT

PhD Thesis by Marcell Mc Knight

APPENDIX L: CONFIRMATION OF PROFESSIONAL EDITING

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25 January 2024

Declaration of editing

THE DEVELOPMENT OF A FRAMEWORK FOR ENHANCING IN-SERVICE LIFE SCIENCES TEACHERS' READINESS TO ADOPT FOURTH INDUSTRIAL REVOLUTION (4IR)-BASED INSTRUCTIONAL STRATEGIES
By
MARCELL MC KNIGHT

I declare that I have edited and proofread this report. My involvement was restricted to language usage and spelling, completeness and consistency. I did no structural re-writing of the content.

I am qualified to have done such editing, being in possession of a Bachelor's degree with a major in English, having taught English to matriculation, and having a Certificate in Copy Editing from the University of Cape Town. I have edited more than 500 Masters and Doctoral theses, as well as articles, books and reports.

As the copy editor, I am not responsible for detecting, or removing, passages in the document that closely resemble other texts and could thus be viewed as plagiarism. I am not accountable for any changes made to this document by the author or any other party subsequent to the date of this declaration.

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