UNIVERSITY OF KWAZULU-NATAL INYUVESI YAKWAZULU-NATALI

COLLEGE OF LAW AND MANAGEMENT STUDIES

An investigation of the readiness of Council for Scientific & Industrial Research software developers for the Fourth Industrial Revolution

Nkosinathi Lucky Mtambo

200300557

A dissertation submitted in fulfilment of the requirements for the degree of Master of Commerce

Graduate School of Business and Leadership

College of Law and Management Studies

Supervisor: Dr Nomkhosi Luthuli

2024

Declaration

I, Nkosinathi Lucky Mtambo, decare that

i. The research reported in this dissertation, except where otherwise indicated, is my original research.

ii. This dissertation has not been submitted for any degree or examination at any other university.

iii. This dissertation does not contain other persons' data, pictures, graphs, or other information, unless specifically acknowledged as being sources from other persons.

iv. This dissertation does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:
   a) their words have been re-written, but the general information attributed to them has been referenced.
   b) where their exact words have been used, their writing has been placed inside quotation marks and referenced.

v. Where I have reproduced a publication of which I am author, co-author or editor, I have indicated in detail which part of the publication was written by myself alone and have fully referenced such publications.

vi. This dissertation does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the dissertation and in the References section.

Signed: ………………………………………………

Acknowledgements

I would like to thank my supervisor, Dr Nomkhosi Luthuli, without whom this study would not have been possible. Thank you for guiding, motivating and inspiring me to strive for the best.

I would like to thank my colleague at CSIR, Prof Marlien Herselman, for her support and guidance in formulating this research topic.

To my father and mother, wherever you are with the angels, I dedicate this to you. To my children Ingakithi and Sabusiswa and their mother, who encouraged me to complete, thank you for your support.

Last, but not least, to the CSIR and NEXTGEN staff. Thank you very much for making this possible.

Abstract

Significant changes have been brought about by the Fourth Industrial Revolution, also referred to as Industry 4.0, as a result of the development of new technology that replaces the human factor with artificial intelligence, robotics, and automation. Many organisations currently have no existing strategy in place to address the needs of Industry 4.0. The purpose of this study is to determine how Industry 4.0 has developed at the Council for Scientific & Industrial Research (CSIR), and the underlying skill sets required for the organisation's software developers to address the challenges posed by this phenomenon. Existing skills are no longer able to prepare software developers to face these challenges, and therefore skills development has become a priority. A sample of 15 experts in software engineering and technologists from the Next Generation Enterprise and Institutions (NGEI) Cluster at CSIR were interviewed by means of semi-structured interviews. Participants identified the need for training and reskilling, continuous learning, improvement of processes to allow for efficiency and sustainability, and for CSIR to train traditional managers as digital leaders. The study recommends that CSIR introduce knowledge-sharing sessions to encourage learning from other developers' experiences, encouragement and support of ongoing educational programmes, training and skills development through various platforms, and that processes need to be re-engineered to address the demands and challenges of Industry 4.0.

Keywords

Fourth Industrial Revolution, Software development, Skills development

TABLE OF CONTENTS

List of tables

List of figures

Acronyms and abbreviations

4IR	Industry 4.0
AU	African Union
CPS	Cyber-physical systems
CSIR	Council for Scientific and Industrial Research
DCDT	Department of Communications and Digital Technologies
DTI	Department of Trade and Industry
IoT	Internet of Things
NDP	National Development Plan
NGEI	Next Generation Enterprise and Institutions
SET	Science, Engineering and Technology
TVET	Technical Vocational Education and Training
UNIDO	United Nations Industrial Development Organisation
WEF	World Economic Forum

CHAPTER 1 – INTRODUCTION

1.1 Introduction

The Fourth Industrial Revolution (4IR) signifies a pivotal shift in technological advancement, characterised by the integration of digital, physical, and biological systems. This revolution is not merely an extension of previous industrial revolutions but represents a transformative change with far-reaching implications for industries, economies, and societies. It encompasses a wide array of technologies, including artificial intelligence (AI), robotics, the Internet of Things (IoT), big data analytics, and biotechnology, among others (World Economic Forum, 2016a). These innovations create unprecedented opportunities for enhancing efficiency, productivity, and sustainability, yet they also pose significant challenges that organisations must navigate to remain competitive (Mkhize, Kayembe & Thusi, 2024).

In the world of software development, the implications of 4IR are particularly pronounced. The rapid pace of technological change necessitates that software developers adapt to new programming languages, tools, and methodologies. Traditional software development practices are increasingly being supplemented or replaced by agile methodologies, DevOps practices, and continuous integration/continuous deployment (CI/CD) pipelines. This shift emphasises the need for developers to be proficient not only in coding but also in collaborative practices that enhance productivity and innovation (Ghobakhloo, 2020; Ivanov *et al.*, 2018).

As organisations strive to harness the potential of 4IR technologies, understanding the readiness of their workforce becomes paramount. Readiness encompasses a range of factors, including technical skills, soft skills, organisational culture, and infrastructure (Saleh & Liab, 2023). Technical skills are essential for effective implementation of advanced technologies, while soft skills such as critical thinking, creativity, and emotional intelligence, are increasingly recognised as vital for fostering collaboration and innovation in diverse teams (Fomunyam, 2020; Kipper *et al.*, 2021). As Schäfer (2018) explains, the integration of AI and machine learning into software development processes exemplifies the need for enhanced skill sets. According to Hmida and Obermayer (2023), developers must now understand how to create algorithms that can learn and adapt, necessitating a deep understanding of data structures, statistical methods, and ethical considerations surrounding AI deployment. The rise of automation means that repetitive coding tasks may become obsolete, compelling developers to focus on more complex problem-solving and design-oriented activities. This evolution in roles necessitates a re-evaluation of educational and training programmes to adequately prepare the workforce for the demands of 4IR (Jelonek *et al.*, 2020).

The 4IR fosters a collaborative ecosystem where cross-functional teams are essential. In a landscape defined by rapid change and uncertainty, organisations increasingly rely on diverse teams that bring together varied expertise and perspectives (Chew *et al.*, 2024). For software development, this means fostering environments where developers, designers, and end-users collaborate closely throughout the product development lifecycle. Agile methodologies have emerged as a preferred framework for managing such collaborative efforts, emphasising iterative development, continuous feedback, and flexibility (Beier *et al.*, 2020).

The advent of 4IR technologies is reshaping job roles and responsibilities within organisations. Many traditional roles may become redundant, while new positions will emerge that require different skill sets (Rashed *et al.*, 2023). For instance, positions such as data scientists, AI ethicists, and automation specialists are becoming increasingly vital. Organisations need to anticipate these changes and develop strategies for reskilling and upskilling their existing workforce. This proactive approach not only addresses potential workforce displacement but also enables organisations to leverage the full potential of emerging technologies. The challenges associated with 4IR are particularly pronounced in developing regions, where organisations often face resource limitations, inadequate infrastructure, and varying levels of digital literacy. In South Africa, for example, the (National Planning Commission, 2020) emphasises the importance of digital readiness for the country's economic future, highlighting the need for targeted initiatives that enable organisations and individuals to adapt to the demands of 4IR. This context underscores the necessity for organisations to develop tailored training programmes that consider the specific needs and circumstances of their workforce.

The Council for Scientific and Industrial Research (CSIR) in South Africa plays a critical role in advancing scientific research and industrial development. As the CSIR aims to position itself at the forefront of 4IR initiatives, it is essential to assess the preparedness of its software developers to navigate this transformative landscape. Despite the increasing recognition of the need for digital readiness, empirical studies specifically focused on the CSIR context are limited. Most existing literature has concentrated on broader aspects of 4IR, often overlooking sector-specific challenges and opportunities that organisations such as the CSIR face in adapting to this new industrial paradigm (Dalenogare *et al.*, 2018; McKinsey Global Institute, 2021).

1.2 Problem statement

The advent of Industry 4.0 is driving unprecedented transformational change across various sectors, characterised by rapid technological advancements that necessitate the emergence of new technical skills (Ghanam *et al.*, 2012). As industries increasingly incorporate technologies such as artificial intelligence, the IoT, and automation, the demand for specific skill sets, particularly in software development engineering, has surged. High learning institutions are responding to this demand by adapting their curricula to ensure that graduates are equipped with the necessary competencies to thrive in an Industry 4.0 environment (Akbar *et al.*, 2020).

In South Africa, the National Development Plan (NDP) places significant emphasis on the creation of employment opportunities and the enhancement of quality education and skills development (Jelonek *et al.*, 2020). In his 2019 State of the Nation Address, the President of South Africa acknowledged the urgent need to adapt to evolving skills requirements. He highlighted the government's commitment to improving training within the education system to better prepare the workforce for future challenges. This call to action underscores the critical importance of conducting thorough research on skills requirements for Industry 4.0 (Motyl *et al.*, 2017).

Research and technical institutions play a pivotal role in this digital transformation ecosystem. These institutions must align their educational frameworks with the skill demands of Industry 4.0 to remain relevant and effective (Vrchota, 2020). The traditional approaches to training are no longer sufficient; instead, there is a pressing need for lifelong learning and continuous professional development. Industry 4.0 has fundamentally altered the landscape of employee training, necessitating innovative pedagogical strategies that can address its unique challenges. Park (2016) notes that the engineering profession is particularly susceptible to the rapid changes brought about by technological advancements, necessitating a robust response from educational institutions.

The World Economic Forum (WEF) emphasises the importance of supporting and strengthening technical institutions, asserting that practical and technical skills are essential for success in an Industry 4.0 context. In this regard, South African technical institutions must prioritise the training of engineering professionals in advanced technologies to ensure they are adequately prepared to meet the demands imposed by Industry 4.0 (African Union, 2019). This preparation is not merely an academic exercise; it is a crucial step towards fostering a workforce capable of navigating the complexities of modern industrial environments.

As Industry 4.0 evolves, software developers will be required to possess specific skills to create innovative products and solutions that enhance client service delivery (Fomunyam, 2020). However, within the CSIR, there are concerns that current software development teams may lack the requisite skill sets to meet the future demands of the Fourth Industrial Revolution. This gap poses a significant challenge for the organisation, as it could hinder its ability to remain competitive and responsive to industry needs. (Ilya and Khan, 2017) note that the rapid pace of technological change means that software developers must continually update their knowledge and skills to keep up with emerging trends and tools. Failure to do so could result in a workforce that is ill-equipped to harness the full potential of Industry 4.0 technologies. This inadequacy not only affects the individual developers but also impacts the broader organisational capacity to innovate and adapt to new market demands.

The implications of these skill gaps extend beyond individual organisations; they can affect national competitiveness in the global economy. As countries strive to position themselves as leaders in technological innovation, a workforce that is not prepared for the challenges of Industry 4.0 can significantly undermine those efforts. Thus, it is essential for educational institutions, industry stakeholders, and government entities to collaborate closely to develop effective strategies for skills development and training. The integration of Industry 4.0 technologies into various sectors also demands a shift in how organisations approach employee training and development (Kosti & Angelis, 2014). Traditional training programmes may not suffice in equipping software developers with the necessary skills to thrive in this new landscape. Instead, a more dynamic and responsive approach to training is required – one that emphasises real-world applications, collaborative learning, and ongoing professional development.

This study aims to investigate the specific skill requirements for software developers at the CSIR in the context of Industry 4.0. By identifying current competencies and pinpointing areas for improvement, the research seeks to provide actionable insights that can inform training programmes and professional development initiatives. Understanding the skill gaps within the CSIR's software development teams is essential for crafting targeted interventions that will enhance their readiness for the future.

The findings of this study will contribute to the broader discourse on skills development in the context of Industry 4.0. By examining the challenges and opportunities presented by emerging technologies, this research will help illuminate the path forward for both educational institutions and industry stakeholders. The goal is to create a workforce that is not only prepared for the demands of the Fourth Industrial Revolution but also capable of driving innovation and contributing to sustainable economic growth.

1.3 Justification of the study

The rationale for this study stems from the urgent need to evaluate and improve workforce readiness in the context of the Fourth Industrial Revolution (4IR) at the Council for Scientific and Industrial Research (CSIR) in South Africa. As organizations increasingly adopt advanced technologies, it becomes essential to understand how well their employees can adapt and succeed in this fast-changing environment. Several important factors highlight the importance of this research.

The Fourth Industrial Revolution is marked by extraordinary technological progress, including innovations like artificial intelligence, automation, and the Internet of Things (IoT), which are rapidly transforming industries (Ghobakhloo, 2020; Ivanov et al., 2018). In this context, organisations must ensure their workforce possesses the skills needed to leverage these technologies effectively (Saleh & Ijab, 2023). Understanding the current readiness of CSIR software developers will provide insights into their ability to navigate these changes.

Existing literature highlights significant gaps in the skills required for successful participation in the 4IR (Dalenogare *et al.*, 2018; Kipper *et al.*, 2021). By systematically assessing both technical and soft skills among CSIR software developers, this study will identify specific areas where training and development are needed. Addressing these gaps is crucial for enabling employees to contribute effectively to the organisation's objectives and technological initiatives (Li *et al.*, 2019).

The CSIR's mission is to drive innovation and contribute to national development through research and technology. A well-prepared workforce is essential for achieving these goals. By analysing the readiness of its software developers, the CSIR can implement targeted training programmes that enhance employee capabilities, leading to improved organisational performance and competitiveness in the global market (Deloitte, 2016; Alcácer & Cruz-Machado, 2019).

Overall, the justification for this study is grounded in the urgent need to understand workforce readiness in the context of the Fourth Industrial Revolution. By focusing on the CSIR and its software developers, the study aims to address critical gaps in knowledge regarding the skills and competencies necessary for thriving in this new industrial landscape. The insights gained from this research will not only benefit the CSIR but also contribute to broader discussions on workforce development, organisational culture, and ethical technology use in developing economies. Ultimately, this study seeks to enhance the CSIR's capacity for innovation and competitiveness, ensuring its continued relevance in an ever-evolving technological environment.

1.4 Aim and objectives of the study

The aim of this study is to assess the readiness of software developers at the CSIR for the Fourth Industrial Revolution.

The objectives of the study are as follows:

- To evaluate the development of Industry 4.0 initiatives at the CSIR.

- To identify the essential skill sets required for the future of software developers at the CSIR to meet Industry 4.0 challenges.
- To explore how software developers can modify their training to align with future requirements.
- To assess the current skills needed by software developers for effective operation at the CSIR (As-Is).
- To identify gaps that must be addressed to prepare software developers for an Industry 4.0 environment (To-Be).
- To determine the current state of readiness for Industry 4.0 among software developers at the CSIR.

1.5 Research questions

The following are the research questions of this study:

- How have Industry 4.0 initiatives developed at the CSIR?
- What essential skill sets are required for the future of software developers at the CSIR to effectively address Industry 4.0 challenges?
- In what ways can software developers adapt their training to meet future requirements?
- What are the current skills necessary for software developers to operate effectively at the CSIR (As-Is)?
- What gaps need to be addressed to equip software developers for success in an Industry 4.0 environment (To-Be)?
- What is the current state of readiness for Industry 4.0 among software developers at the CSIR?

1.6 Methodology

The methodology used in the study is briefly discussed in this section.

1.6.1 Research approach

This study employed a qualitative research design to explore the workforce readiness of software developers at the CSIR in the context of the Fourth Industrial Revolution

(4IR). The qualitative approach was selected to gain in-depth insights into the experiences, perceptions, and competencies of software developers, focusing on their technical and soft skills as well as the organisational challenges they faced.

1.6.2 Sampling and participants

A purposive sampling technique was used to select participants for this study. The sample comprised 15 software developers employed at the CSIR. This sample size was deemed appropriate to allow for an in-depth exploration of the participants' perspectives while remaining manageable within the study's timeframe and resource constraints. The participants were selected based on their involvement in software development projects relevant to 4IR technologies, ensuring that they had sufficient experience and expertise to provide meaningful insights into the research topic.

1.6.3 Data collection

Semi-structured interviews were the primary method of data collection. The researcher developed the interview questions, which were designed to explore the participants' perceptions of their readiness for 4IR, their technical and soft skills, and the challenges they encountered in adapting to the evolving technological landscape. The semi-structured format allowed for flexibility, enabling the researcher to probe deeper into specific responses while ensuring that all key topics were addressed consistently across interviews.

The interview guide covered the following key themes:

- Participants' understanding of 4IR and its implications for software development.
- Self-assessment of technical and soft skills relevant to 4IR technologies.
- Perceived challenges and opportunities in adapting to 4IR demands.
- Organisational support and resources available for skill development and readiness.

Each interview lasted approximately 45–60 minutes and was conducted in a private setting to ensure confidentiality and encourage open communication. With the participants' consent, the interviews were audio-recorded for accuracy and later transcribed verbatim for analysis.

1.6.4 Data analysis

Thematic analysis was used to analyse the interview data. This involved familiarising the researcher with the data through repeated reading of the transcripts, coding significant statements, and identifying patterns and themes related to workforce readiness. The identified themes were then reviewed and refined to ensure they accurately represented the data and addressed the research aims.

1.7 Limitations of the study

The following limitations were acknowledged:

- The study's findings were constrained by the small sample size of participants. A limited number of respondents affected the generalizability of the results. While the study provided in-depth insights into the experiences and perceptions of the selected software developers, it did not fully capture the diverse perspectives and readiness levels of all developers within the CSIR or the broader industry. This limitation restricted the applicability of the findings to other contexts or organisations.
- The study utilised a qualitative research methodology, which, although rich in detail and context, introduced subjectivity in data interpretation. Qualitative data was often influenced by the researchers' biases and the participants' perspectives, leading to variations in findings. Additionally, qualitative studies typically did not provide quantifiable measures of workforce readiness, making it challenging to draw definitive conclusions about the overall preparedness of the workforce. The reliance on interviews and focus groups limited the breadth of data collected, as not all relevant aspects of workforce readiness were encompassed.
- The study focused exclusively on the CSIR, limiting the broader applicability of its findings to other organisations or sectors. The unique organisational culture, structure, and challenges faced by the CSIR were not representative of the experiences encountered by software developers in different contexts or industries. Consequently, the insights gained were not universally applicable.
- The study's timeframe posed additional limitations, as workforce readiness was a dynamic concept that changed rapidly in response to technological advancements and organisational changes. The findings reflected a snapshot

of the current state of readiness but did not account for future developments or shifts in the technological landscape that could influence workforce skills and competencies.

1.8 Outline of the research

CHAPTER 1 – INTRODUCTION

Provides an overview of the study, including an introduction and background to the research.

CHAPTER 2 – LITERATURE REVIEW

Outlines the literature review based on the secondary data that has been previously researched.

CHAPTER 3 – RESEARCH METHODOLOGY

Presents a description of how the research will be done, including research methodology and the design

CHAPTER 4 – FINDINGS AND ANALYSIS

Present raw data collected through data collection process; this includes online interviews with software developers.

CHAPTER 5 – RECOMMENDATIONS AND CONCLUSION

The findings are discussed, followed by conclusion, recommendations, and the reflection of the researcher.

CHAPTER 6 – REFERENCES

Provides a list of references cited during the study.

APPENDICES

CHAPTER 2 – LITERATURE REVIEW

The literature review will be divided into five themes. The study will explore the impact of Industry 4.0 on skills development for technical and research institutions in the international and African landscape, and further review literature with specific reference to South Africa. Skills development refers to the process of identifying skills gaps and ensuring that these skills are developed (Shafer, 2018), and this concept must guide the scope of this study's objectives. The theoretical framework supporting this study will be discussed, i.e. the demands of Industry 4.0 on software development with emphasis on skills training and policy documents. The study will further investigate the measures institutions of higher learning are taking to address Industry 4.0 in the software development space.

Technology is driven by disruption and innovation (Motyl *et al.*, 2017). The digital landscape is transforming at an accelerating speed and companies are faced with high levels of uncertainty about the future. Mzekandaba (2020) claims that organisations realise that to succeed in a digital space, they should not only rely on cutting-edge technology but also on future-fit employees who can thrive with the latest technological tools. According to Oztemel and Gursey (2018), organisations need to invest in people who are unable to adapt to the future needs of Industry 4.0. They further state that organisations need people who can learn and upskill in order to succeed in Industry 4.0 and that without these people, the possibility of failure cannot be excluded. (Stray & Moe, 2018) concludes that digital talent triggers transformation.

2.1 The evolution of the Industrial Revolution

The First Industrial Revolution, spanning from 1760 to 1840, introduced mechanised production, leading to enhanced efficiency with hydropower, steam power and the development of machine tools (Masko & Krapež, 2016). The Second Industrial Revolution, at the beginning of the 20th century, introduced mass production characterised by electrified assembly lines (Putzier, 2017). The Third Industrial Revolution accelerated the digital automation of production by means of electronics and information technology (Olaitan *et al.*, 2021). It is suggested that the Fourth Industrial Revolution is currently emerging and is driven by cyber-physical systems (CPS) that integrate the real world with the virtual world (Dalenagare *et al.*, 2018).

Some authors have criticised this evolutionary model and argue that we are not yet in the Fourth Industrial Revolution (Stray & Moe, 2020; Dalenogare *et al.*, 2018). They argue that each acknowledged Industrial Revolution disrupted all sectors of society and that, in contrast, the current technological disruption is a "disruptive effect" or evolution of the Third Industrial Revolution.

The Fourth Industrial Revolution has far-reaching implications, and changes how people interact with technology and how work gets done (Roblek *et al.*, 2016). In countries such as Brazil, Germany and India, progress is visible. The delay in other countries largely depends on how to address the different approaches to digitisation and automation.

Kipper *et al.* (2021) question the notion of a Fourth Industrial Revolution and argue that premature excitement is motivated by marketing. The authors maintain that the minimum architectural requirements, which include cyber security, data privacy, stability and investment protection, are not yet mature enough to support it. They do, however, concede that the convergence that underpins the Fourth Industrial Revolution is in the inevitable future. Ivanov *et al.* (2018) refute the contribution of Industry 4.0 to reindustrialisation but acknowledge three categories of consequences at the economic level for developed countries. These are restoring the price competitiveness of industrial units, improving non-price competitiveness, and producing individual units at accessible prices (Beier *et al.*, 2020).

In 2011, Germany presented its Industry 4.0 strategic plans to remain competitive in the manufacturing landscape (Culot *et al.*, 2020a). This has been triggered by the evolution of Industry 4.0. Major consulting companies are also presenting white papers in preparation for the Industry 4.0 revolution and beyond.

2.2 Towards defining the term

According to Culot *et al.* (2020), the definition of Industry 4.0 refers to CPS, interoperability and cybersecurity solutions, which emerge repeatedly with smart and cloud solutions, whereas Alcácer and Cruz-Machado (2019) define Industry 4.0 as automation and digitisation processes, electronics and IT. The World Economic Forum, at Davos 2016, focused instead on the impact of the Fourth Industrial Revolution on businesses, industries, and humanity. This focus was embedded in the belief that the technological changes currently predicted have the potential to disrupt industries, businesses, and global markets.

Inspired by this anticipated future, the term Industry 4.0 was introduced in 2011 in Germany as part of a proposal aimed at creating a new economic policy focused on high-tech strategies (Woetzel, 2019). The excitement surrounding the term stems from the belief that disruptions can be anticipated and effectively planned for (Malik, Z., & Pusha, U., 2024).

General Electric expresses a comparable concept known as the Industrial Internet, which is described as “the combination of intricate physical machinery and devices with networked sensors and software, utilized to anticipate, manage, and strategize for improved business and societal results” (Ghanam et al., 2012). The excitement surrounding this term stems from the belief that this disruption can be anticipated and thus effectively planned for (Khan et al., 2016).

According to Schwab, Chairman and Founder of the World Economic Forum, “We are at the beginning of a revolution that is fundamentally changing the way we live, work, and relate to one another. In its scale, scope and complexity, what I consider to be the fourth industrial revolution is unlike anything humankind has experienced before.” The term Industry 4.0 is used interchangeably with the *Fourth Industrial Revolution*, depending on the focus of the authors (Ilyas & Khan, 2017).

Industry 4.0 focuses on manufacturing and logistics and is seen as a part of the Industrial Internet, which also considers the product life cycle (Roblek et al. 2016). The concept of the Industrial Internet is bolstered by U.S. government funding for "advanced manufacturing," which encompasses both innovative methods for producing existing products and the creation of new products arising from cutting-edge technologies (Stray & Moe, 2020). Similar ideas are encapsulated by terms such as Integrated Industry, Smart Industry, and Smart Manufacturing (Vrchota, 2019). Some commentators have, in addition, used the terms “Internet of Things“, “Internet of Everything“ and “Smart Factory“ (Kosti *et al.*, 2014).

In general, these terms are used to describe an emerging technological revolution and have in common the recognition that traditional manufacturing and production methods are undergoing a digital transformation.

2.3 Impact of technological advances

The First Industrial Revolution brought water and steam power for mechanical manufacturing (Melaletsa et al. 2023). The Second Industrial Revolution leveraged electrical energy to enable mass production. The Third Industrial Revolution introduced automation through electronics and information technology (Mtshali & Jili, 2022). The Fourth Industrial Revolution builds on the Third by implementing intelligent production that integrates the Internet of Things, cloud technology, and big data (World Economic Forum, 2016a).

The idea of Industry 4.0 was first presented in 2011 across multiple sectors, including business, politics, and academia, with the goal of boosting competitiveness in German manufacturing (Oztemel & Gursev, 2018). Industry 4.0 refers to the structuring of production processes where technology and devices communicate autonomously with one another throughout the value chain (Carlberg et al., 2016).

Industry 4.0 started 30 years later (Matthias, 2018), combining technology and human capacity in a usual way of self-learning algorithms and bid data analytics, and Alcácer and Cruz-Machado (2019) argue that the notion is true because Industry 4.0 offers a chance to align the goals for sustainable development. In the early 2000s, industry policies faced many challenges to improve productivity levels and increase competitiveness, and that led to new thinking when the crisis struck in 2008-2009. The European Union has developed its Industry 4.0 policy aimed at generating an "Industrial Renaissance" in Europe (Carlberg *et al.*, 2016), while industry policy developers within European Union countries were also navigating and assessing several issues around Industry 4.0 policy initiatives.

In October 2012, the European Commission released a publication called "A Stronger European Industry for Growth and Economic Recovery," which highlighted that "... a robust industrial foundation is crucial for a prosperous and economically successful Europe." and a number of approaches were then formulated by member states to endorse industry policy development (Carlberg, 2016). The current impact of Industry 4.0 is relatively low in South Africa compared to the rest of the world to the extent that emerging countries are faced with more challenges compared to the rest of the world, and this has been acknowledged by the rest of the world (World Economic Forum, 2016).

What remains a challenge in Africa is connectivity and accessibility. According to Carlberg *et al.* (2016), the acknowledgement of these challenges will drive broader adoption of Industry 4.0. Developing countries need to devote more investment to new technologies and knowledge within the industry and government at large. Organisations and businesses should strive to invest in innovation rather than saving costs (Carlberg *et al.*, 2016). This is largely because not many applications have been developed as yet. There are opportunities that exist for government to collaborate with research institutions; however, education about topics related to Industry 4.0 and their benefits for policymakers is needed.

In South Africa, Industry 4.0 offers opportunities to create new business models (Department of Communications and Digital Technologies, 2020), and this will enable faster and simpler service delivery to stakeholders. Industry 4.0 offers opportunities to improve operational efficiencies through access to data (Kipper *et al.*, 2021) and this is achieved through the data that is collected from machines and other Industry 4.0 technological mechanisms to enable faster decision-making. Data is transformed into useful information by means of graphical representation or dashboards, and these are easily interpreted to make fact-based decisions (Daniel *et al.*, 2024). Real-time technology, together with transparency, has the ability to make developments and other processes more efficient (Motyl *et al.*, 2017). Industry 4.0 brings opportunities for South African industries to re-invent themselves, become more competitive, and achieve success in local and global markets.

Industry 4.0 has brought significant changes, and these are related to technological competences and processes (Lu, 2017). An increase in digitisation has put enormous pressure on how businesses operate and has led to the emergence of new models. The adoption of sophisticated information technology is shutting down the boundaries between the real and virtual worlds (Motyl *et al.*, 2017). Today, social networks link information technology with electronic and mechanical components to enable engagement between one another. Mittal *et al.* (2018) suggest that smart systems can interchange information, and this argument is valid because these systems can facilitate and coordinate processes to improve efficiency.

Various studies have demonstrated that Germany and other European countries are advocates of Industry 4.0.

According to (Mangwanta & Uwizeyimana, 2021), Industry 4.0 has seen technological opportunities from a commercial point of view. The majority of businesses that have done studies believe that change is inevitable and that Industry 4.0 will improve their competitiveness through digital transformation, while the minority of businesses see these changes as having an impact on their businesses. The World Economic Forum report *The Future of Jobs Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution* (2016b) suggests that 90% of Federation of Germany industry members recognise the threats posed by Industry 4.0 while 10% feel that they are prepared. A report by Deloitte (Kaiser, 2016) suggests that lack of technological interface can be a key threat to the success of Industry 4.0. Digitalisation offers new opportunities through e-commerce, reducing red tape and minimising trade costs.

African countries continue to face challenges related to infrastructure and technological gaps while policymakers have identified opportunities of digital trade (African Union, 2019). African countries claim a small proportion of e-commerce revenue. According to (Ghobakhloo 2020), Industry 4.0 increases the speed of innovation and benefits employers. This is emphasised by (Culot *et al.* 2020), who lament the shift from centralised to decentralised smart manufacturing and production.

Industry 4.0 is a new industrial stage that integrates operations systems and information and communications technology (ICT) such as IoT, resulting in CPS (Marnewick & Marnewick, 2020). This new era affects competition rules and customers' demands (Van Dyk *et al.*, 2019). It is reconfiguring the completion rules because companies' business models are restructured because of the adoption of Industry 4.0 technologies. From a business perspective, Industry 4.0 offers digital solutions for customers; hence, there is a need to reconsider the skill sets available and determine whether they meet the demands of the engineering industry (Norton *et al.*, 2024).

South Africa should create a comprehensive digital policy that prioritizes artificial intelligence, machine learning, blockchain, and drones. A range of initiatives to contribute to the capacity needed to meet the challenges arising from the deployment and adoption of the digital economy is recommended (Department of Communications and Digital Technologies, 2020). Digital skills should be given attention, especially emerging new areas of skills development and new technology applications.

Addressing skills development in the technology and engineering space is of paramount importance to address the requirements and challenges of Industry 4.0 (National Planning Commission, 2020). The (DCDT, 2020) has recommended a structured series of initiatives to contribute to the capacities needed to meet the challenges arising from the deployment and adoption of the digital economy.

2.4 Impact on education and skills development

The adoption of Industry 4.0 technologies is still in its infancy in South Africa, particularly among rural populations, where awareness remains limited (World Economic Forum, 2016). In contrast, European nations such as Austria, Germany, the Netherlands, Italy, France, and the UK have actively engaged with the implications of Industry 4.0, benefiting from their robust economies and public discourse surrounding technological advancements. This disparity highlights a significant challenge in developing countries, where public awareness and understanding of Industry 4.0 initiatives are insufficient. Policymakers must implement strategies to enhance public engagement and education regarding these developments, ensuring that communities are informed about the potential impacts and opportunities presented by such technologies (Malaysian, 2018).

A critical aspect of successful Industry 4.0 implementation is the wide array of skills required across the entire value chain. Carlberg *et al.* (2016) emphasise that the integration of information technology with advanced capabilities, such as software development, necessitates targeted training and development initiatives to nurture a skilled workforce. This need is underscored by the evolving nature of job profiles, which are increasingly shifting in both content and environment due to technological advancements. As (Fomunyam,2020) notes, the convergence of virtual platforms with physical systems demands coordinated decision-making processes that empower employees to manage their projects while fostering effective communication and collaboration. However, these changes also introduce significant tensions and challenges, as highlighted by (Ali *et al,* 2018), who discuss the complexities of navigating a rapidly evolving work landscape.

The transition to virtual work environments poses additional challenges, as employees may experience feelings of alienation and a loss of control over their work. While the flexibility of working remotely can enhance job satisfaction, it can also lead to overwork and diminished productivity (Marnewick & Marnewick, 2020). Furthermore, the increasing atomisation of skilled and semi-skilled workers may exacerbate existing disparities within the workforce. The introduction of intelligent systems not only transforms job roles but also necessitates an urgent re-evaluation of skill sets required in various professions, particularly in engineering, where graduates must adapt to new technological demands (Marnewick & Marnewick, 2020).

(Mohammed *et al.*, 2020) argue that the development of new expertise and enhanced knowledge is critical to meeting the employment demands of Industry 4.0. This assertion is particularly relevant given the observed gap in preparedness among engineering graduates, who often lack the requisite knowledge and skills to thrive in an Industry 4.0 environment. The rising unemployment rates linked to this skills deficiency underscore the urgent need for interventions aimed at developing a readiness model for graduates (DTI, 2017). Marnewick and Marnewick (2020) further contend that the demand for competent and highly qualified graduates across various sectors necessitates a re-evaluation of educational models and frameworks to better align with the challenges posed by Industry 4.0.

Considering these findings, Haimi (2019) advocates for a comprehensive revision of the educational curriculum to ensure compliance with the innovations of Industry 4.0. This update should focus on cultivating pertinent skills and knowledge, allowing graduates to effectively navigate the challenges of a swiftly evolving job market. The existing literature suggests that without such measures, the potential benefits of Industry 4.0 may be realised unevenly, exacerbating existing inequalities and hindering the overall economic progress of developing nations such as South Africa. Digital capabilities largely depend on how the components of work are assembled, and decisions in this regard are based on the individual experiences of line managers. The necessary data to assemble work and its components largely entails the measurement of workpieces, which are acquired by rules (Li *et al.*, 2019). Currently, the work in many organisations depends on IT systems (Beier *et al.*, 2020). Information, data and processes are captured and stored in IT systems and this information is integrated for use by and dissemination to external and internal stakeholders.

2.5 The demands for Industry 4.0 for software developers

Engineering education is undergoing significant transformation in response to rapid technological advancements, increasing globalisation, and the diversification of engineering student populations (Fomunyam, 2020). As the demand for skilled professionals changes, it is crucial to tackle the skills gap present in the context of Industry 4.0. This gap includes not only technical skills but also emphasizes the importance of soft skills that promote effective collaboration and communication among engineering professionals (Jelonek et al., 2020). Despite recognising the importance of these competencies, there remains a notable deficiency in the development of soft skills within engineering education across Africa, indicating a critical area for reform.

The literature suggests that a robust refocus on the quality and enhancement of essential skills is imperative to meet the expanding demands of engineering programmes, particularly in relation to planning and labour market assessments. As the educational landscape evolves, it is essential that engineering curricula incorporate both technical and soft skills training aligned with the requirements of Industry 4.0 (Deloitte, 2016a). This alignment will better equip software developers and engineers to perform their roles effectively within increasingly complex work environments.

To address the identified soft skills gap, several strategies can be implemented. First, it is essential that engineering educators possess a deep understanding of their discipline, supplemented by adequate professional support skills acquired through higher learning opportunities. This foundational knowledge will enable educators to effectively convey critical soft skills to their students (African Union, 2019). Second, increasing funding for engineering programmes that provide both technical and soft skills training is necessary to ensure that the curriculum remains relevant and responsive to industry needs. Such funding would facilitate the development of programmes that align with Industry 4.0 initiatives, thus preparing graduates for future jobs.

Promoting skills development initiatives for both engineering students and educators is crucial for enhancing collaboration and employability in the future job market. As noted by the (African Union ,2019), it is vital to provide relevant engineering education that prepares future graduates to navigate their educational paths and access employment opportunities without significant challenges. This proactive approach is essential for bridging the skills gap and ensuring that graduates can meet the evolving demands of the industry.

The current labour market presents a stark reality for employers, who often struggle to find and retain talent that meets their needs. This mismatch in skills leads to considerable human capital shortages in a competitive environment, with forecasts suggesting a global deficit of 40 million workers with tertiary education and 45 million with secondary education, alongside a surplus of 95 million low-skilled workers (Deloitte, 2016a). The situation underscores the pressing need for educational reforms that address the skills mismatch, as high-skilled workers increasingly fill high-paying jobs while low-skilled workers remain relegated to low-paying positions.

Promoting skills development initiatives for both engineering students and educators is crucial for enhancing collaboration and employability in the future job market. As noted by the (African Union, 2019), it is vital to provide relevant engineering education that prepares future graduates to navigate their educational paths and access employment opportunities without significant challenges. This proactive approach is essential for bridging the skills gap and ensuring that graduates can meet the evolving demands of the industry.

The current labour market presents a stark reality for employers, who often struggle to find and retain talent that meets their needs. This skills mismatch creates significant human capital shortages in a competitive landscape, with projections indicating a global shortage of 40 million workers with tertiary education and 45 million with secondary education, juxtaposed with a surplus of 95 million low-skilled workers (Deloitte, 2016a). This situation underscores the pressing need for educational reforms that address the skills mismatch, as high-skilled workers increasingly fill high-paying jobs while low-skilled workers remain relegated to low-paying positions.

2.6 Impact of Industry 4.0 skills requirements

Industry 4.0 has changed work processes, which requires employees to reskill themselves to adapt to these new work processes. Mzekandaba (2020) suggests that Industry 4.0 will transform employee work profiles, as employees will be expected to be able to perform both existing and new jobs. (Shafer, 2018) further suggests that a collaborative environment should be in place to allow robotics to interact with humans in the workplace. Automation must be tailor-made depending on the nature of the work to be done. Humans must adapt to Industry 4.0 demands and develop logic that will accommodate the advancement of robots. In addition, a collaboration of machines and humans will improve productivity levels (Deloitte, 2016b).

Table 2.1 lists the current drivers of change in Industry 4.0, the convergence of digital fields, and the roles that engineers will play in this environment.

Table 2.1: Drivers of change in Industry 4.0

Current drivers of change in Industry 4.0	Digital field for Industry 4.0	Roles for engineers in Industry 4.0
Internet of Things (IoT)	Robotics	Forming nanotechnology
Biotechnology	Machine learning	Developing machinery and robotics
Blockchain technology	Nanotechnology	Constructing smart tracking tools and systems
Cloud technology	Biotechnology	Improving sustainable power technologies

Current drivers of change in Industry 4.0	Digital field for Industry 4.0	Roles for engineers in Industry 4.0
Big data analytics	Artificial Intelligence	Crafting 3D printers

Figure 2.1 identifies and describes skill categories needed for the future, provides examples of skills required, and offers recommendations for teaching and training approaches that could be used in an educational setting.

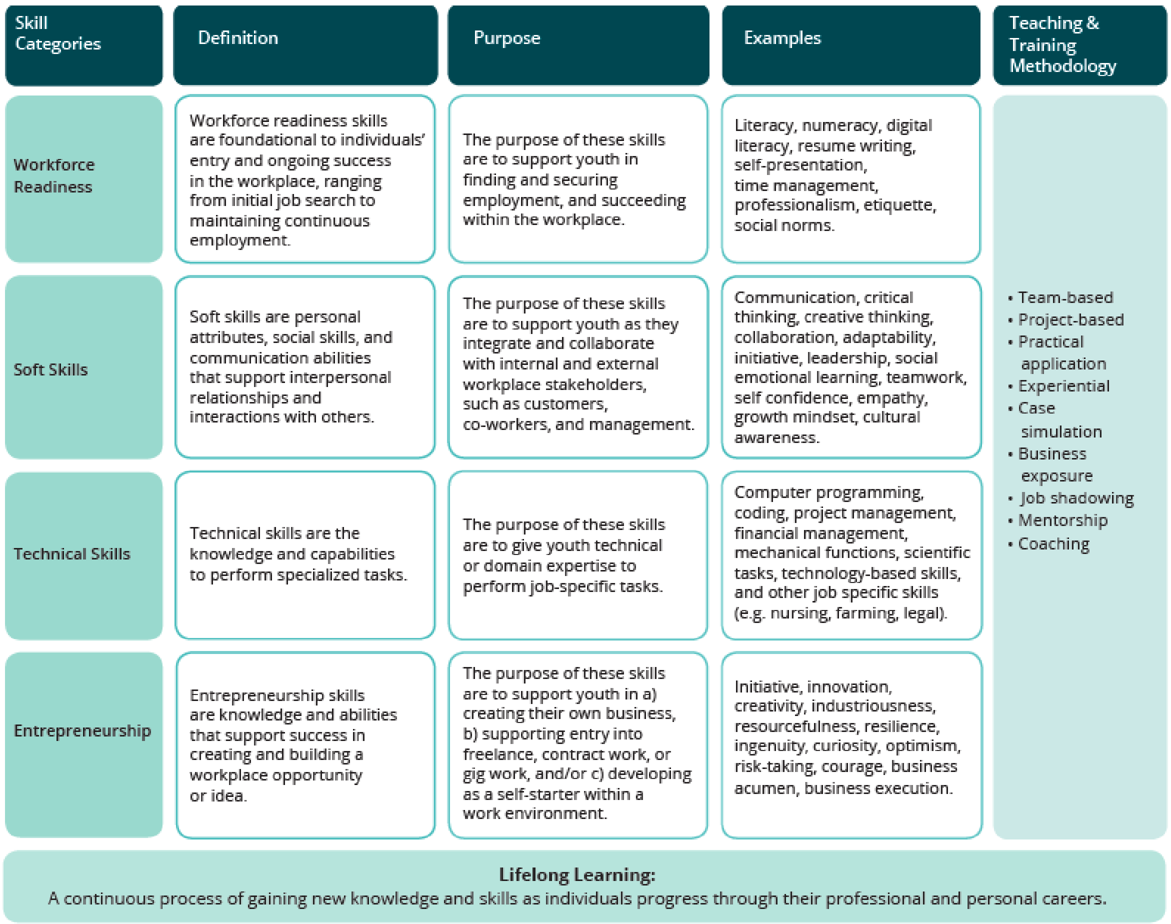

Figure 2.1: Skill sets for the future workforce

Source: Unesco (2012)

2.7 The skills required for software engineers

The adoption of Industry 4.0 necessitates a set of skills across the value chain of the organisation at both operational and support levels (Deloitte, 2016a). Park (2016) suggests that investment in skills development will automatically reduce the unemployment rate among software developers. Industry 4.0 has led to significant challenges in terms of skills shortages in South Africa as compared to the rest of the world.

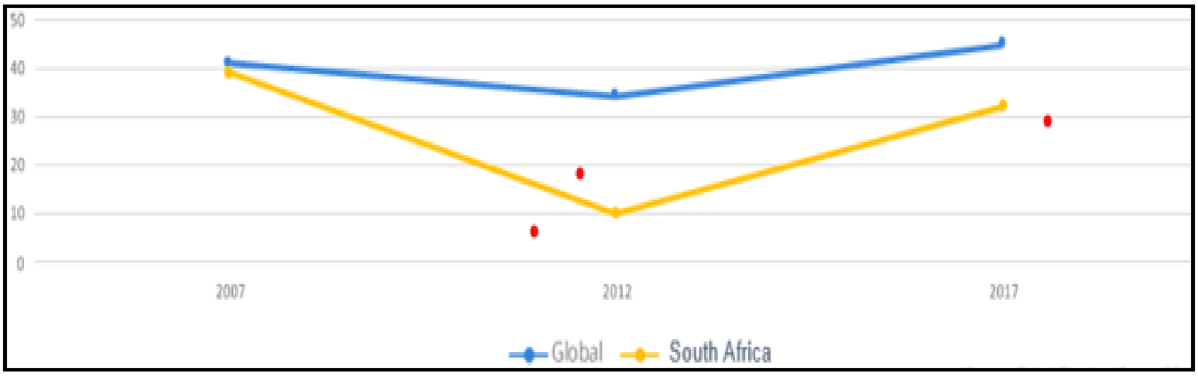

Figure 2.2: Talent shortage (%)

Source: Deloitte (2016a)

Industry bodies must accelerate the development of appropriate skills. Matthias (2018) outlines the ten most appropriate skills for engineers as accredited by engineering bodies; however, these skills are no longer relevant to Industry 4.0.

Table 3.2: Existing skills before Industry 4.0

PREFERRED SKILLS BEFORE INDUSTRY 4.0	
Leadership	Problem-solving
Critical thinking	Communication
Decision-making	Ethics and professionalism
Technology	Teamwork
Management	Lifelong learning

Source: Woetzel (2019)

Technical skills are significant for the smooth operation of the organisation (Matthias, 2018). According to Beier *et al.* (2020), technical and information technology skills are crucial and employers who encourage a facilitated work approach prefer and appreciate soft skills Industry 4.0 is shifting from conventional engineering towards data-driven operations, as well as virtual and artificial systems. In line with this principle, support frameworks within emerging business models should be capable of adapting to new approaches that incorporate innovative technologies. Universities and other educational institutions should establish a strong foundation in ICT skills to ensure that students develop essential ICT literacy and problem-solving abilities. Technical skills associated with the job are significant for the smooth operation of the organisation (Matthias, 2018).

The World Economic Forum (2016a) published a set of skills in demand for Industry 4.0 and made a comparison for between 2018 and 2022 (see Table 2.3 below).

Table 2.3: Skills in demand for Industry 4.0

Year 2018		Year 2022	
1	Analytical thinking and innovation	1	Analytical thinking and innovation
2	Complex problem-solving	2	Active learning and learning strategies
3	Critical thinking and analysis	3	Creativity, originality and initiative
4	Active learning and learning strategies	4	Technology design and programming
5	Creativity, originality and initiative	5	Critical thinking and analysis
6	Attention to detail and trustworthiness	6	Complex problem-solving
7	Emotional intelligence	7	Leadership and social influence
8	Reasoning, problem-solving and ideation	8	Emotional intelligence
9	Leadership and social influence	9	Reasoning, problem-solving and ideation
10	Co-ordination and time management	10	System analysis and evaluation

Source: World Economic Forum (2016b)

Government, business and individuals are likely to face challenges with identifying future skills that are relevant for future jobs (African Union, 2019). The sentiment is valid because relevant skills are necessary to address the demands of Industry 4.0 and to meet future business needs. According to Mzekandaba (2020), business has invested more effort into SET (Science, Engineering and Technology) graduates produced by the public education system. Businesses need to remodel their operational strategies in order to accommodate the technology transformation that Industry 4.0 has introduced. In light of this, businesses have the opportunity to use new technology to grow their job market and business, and to produce innovative products and solutions. It is important for businesses to reskill and upskill their existing workforce.

2.8 Skills gaps and development

Companies need to improve and harness existing skills in order to maximise their productivity at a reduced cost of reskilling. Various countries define the challenges of skills gaps and development by conducting global comparisons between relevant variables. Figure 2.3 below highlights the need for more upskilling and reskilling programmes to address Industry 4.0 demands, and Figures 2.4 and 2.5 comparisons prove the case that skills development should have a positive effect. In Brazil, between 2012 and 2017, workforce challenges have been largely driven by lack of required hard skills and experience.

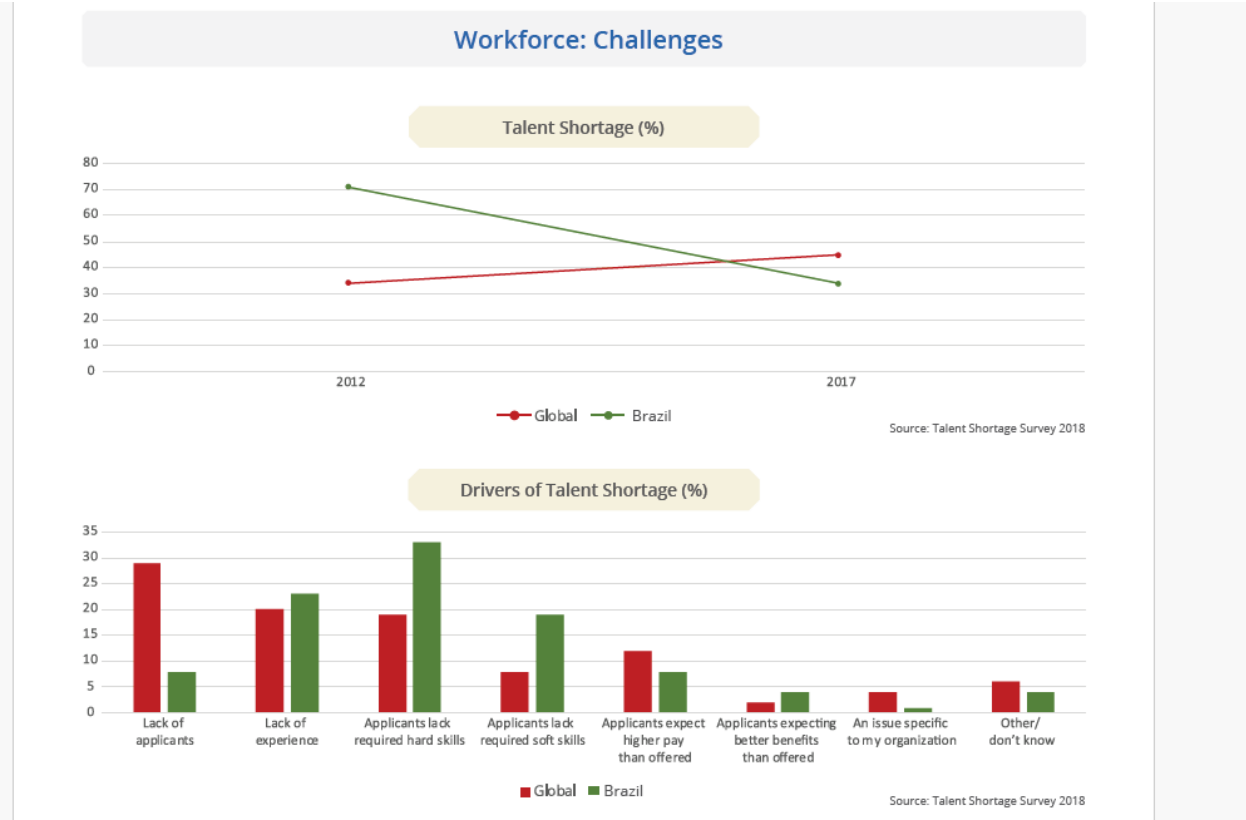

Figure 2.3: Workforce challenges

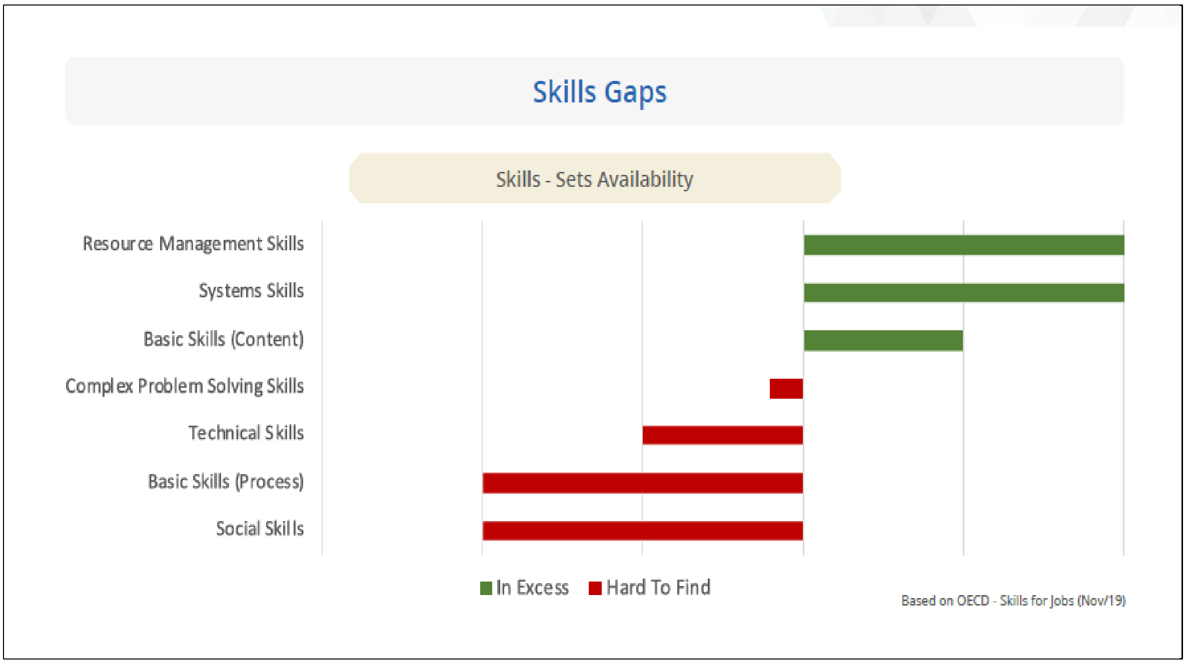

Figure 2.4: China skills gaps and skills developments (future jobs)

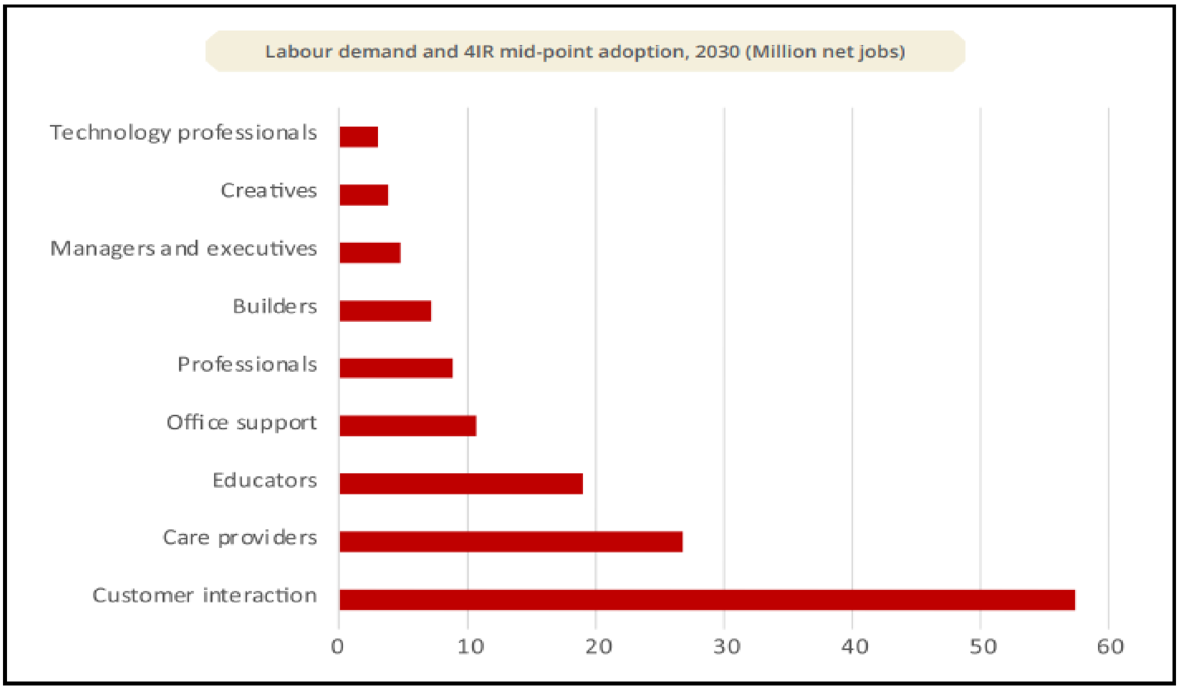

Figure 2.5: Labour demand and Industry 4.0 adoption

Source: Woetzel (2019)

A technology report by Malaysian (2018) suggests that countries should learn from China, as it has been able to launch a plan to encourage the adoption of cloud computing for the future. India has also encouraged businesses to move towards digital production technologies in New Delhi and Pune (Van Dyk *et al.*, 2019).

China is a global leader in the use of robotics while countries such as India and Turkey are also moving towards the use of robotics. Japan produces robots at a large scale, and both China and Japan have policies that strongly support the adoption and implementation of new technologies. The two countries have invested in and devoted efforts to industrial robot research and development, funded by their respective governments. South African Industry 4.0 policies should align with sector policies if the country is to respond to the demands of Industry 4.0 (Deloitte, Quoted in Kaiser, 2016).

In South Africa, lack of industry-level data has compromised the work of the policymakers; hence, they are unable to bring options, solutions and interventions that could assist industries (McKinsey Global Institute, 2017). Collaboration networks must be established for companies (Department of Communications and Digital Technologies, 2020). This sentiment is positive because collaboration among manufacturers in South Africa can provide opportunities to discover technologies that will reduce costs in terms of their production lines.

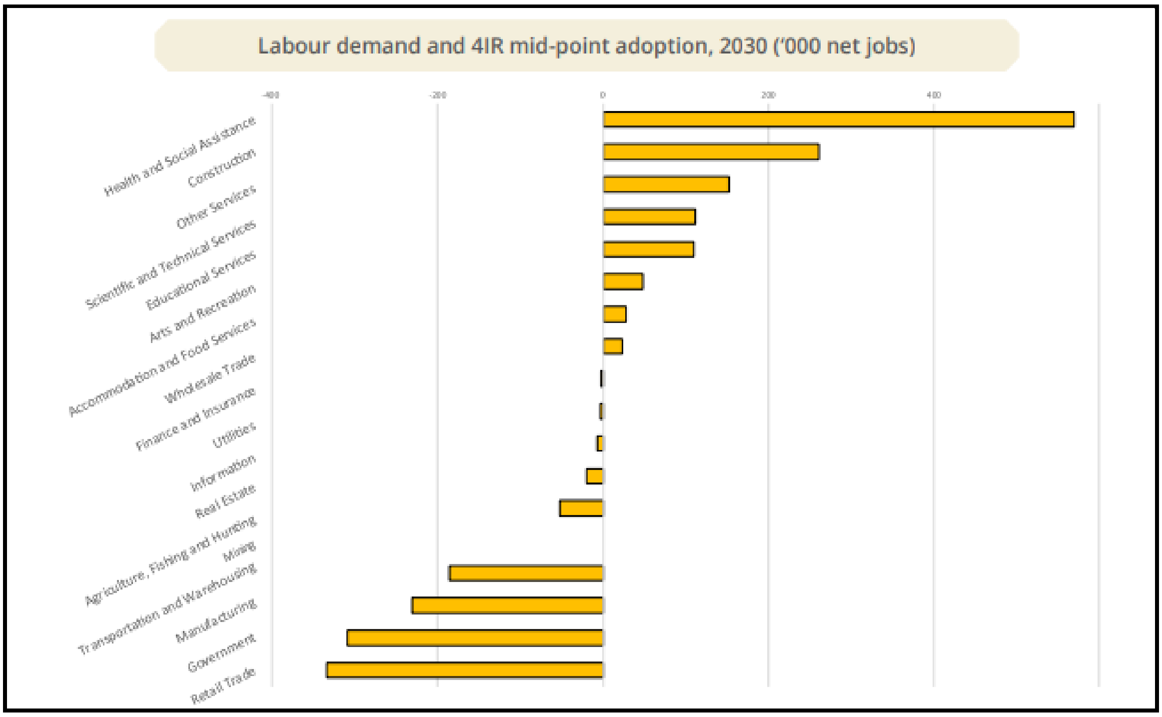

Figure 2.6: South Africa skills gaps and skills developments (future jobs)

Source: Woetzel (2019)

Jelonek *et al.* (2020) emphasise that digitisation expertise does not reside with individuals or organisations but rather through collaborative platforms. The South

African government should connect technological hubs to achieve positive outcomes through collaborative networks (National Planning Commission, 2020). Institutions of higher learning should formulate a curriculum that incorporates data engineering and machine learning applications, while Technical Vocational Education and Training (TVET) institutions should improve the supply of medium-level technical skills (DCDT, 2020).

Table 2.4: Current skills needed for Industry 4.0

Skills Categories	Definition	Purpose	Examples	Teaching & Training Methodology
Workforce Readiness	Foundational to individual's entry and ongoing success in the workplace, ranging from initial job search to maintaining continuous employment	To support youth in finding and securing employment and succeeding within the workplace	Literacy, numeracy, digital literacy, resume writing, self-presentation, time management, professionalism, etiquette, social norms	• Team-based • Project-based • Practical application • Experiential • Case simulation • Business exposure • Job shadowing • Mentorship • Coaching
Soft Skills	Personal attributes, social skills and communication abilities that support interpersonal relationships and interactions with others	To support youth as they integrate and collaborate with internal and external workplace stakeholders	Communication, critical thinking, creative thinking, collaboration, adaptability, initiative, leadership, social emotional learning, teamwork, self-confidence, empathy, growth mindset, cultural awareness	
Technical Skills	Knowledge and capabilities to perform specialised tasks	To give youth technical or domain expertise to perform job-specific tasks	Computer programming, coding, project management, financial management, mechanical functions, scientific tasks, technology-based skills, and other job-specific skills (e.g.,	

Skills Categories	Definition	Purpose	Examples	Teaching & Training Methodology
			nursing, farming, legal)	
Entrepreneurship	Knowledge and abilities that support success in creating and building a workplace opportunity or idea	To support youth in establishing their own business, support entry into freelance, contract work and/or developing as a self-starter within a work environment	Initiative, innovation, creativity, industriousness, resourcefulness, resilience, ingenuity, curiosity, optimism, risk-taking, courage, business acumen, business execution	

Lifelong Learning:

A continuous process of gaining new knowledge and skills as individual's progress through their professional and personal careers.

Source: Deloitte (2016b)

The level of uncertainty when it comes to the appropriate workforce and skills needed for the future is too high (Department of Trade and Industry, 2017). The categories as outlined in Table 2.4 above provides a framework to prepare for future jobs and skills and promote lifelong learning for growth (Jelonek *et al.*, 2020). The technical skills shown in the framework above are relevant to software developers. Kipper *et al.* (2021) suggest that for the industry to understand technical skills, they must conduct industry research first. This recommendation is useful since inputs need to be gathered from various players within the industry so that existing theories and frameworks can be redefined to enhance education and training programmes that will address the needs of Industry 4.0.

2.9 Theoretical Framework: Lewin's Theory of Change

Kurt Lewin's Theory of Change provides a comprehensive framework for understanding and facilitating organisational change, particularly relevant in the context of adapting to Industry 4.0. Developed in the 1940s, Lewin's model outlines a three-step process: Unfreeze, Change, and Refreeze. This framework is crucial for organisations such as the Council for Scientific and Industrial Research (CSIR), as it emphasises the necessity of preparing individuals and entities for change, implementing new practices, and solidifying those changes to ensure lasting impact.

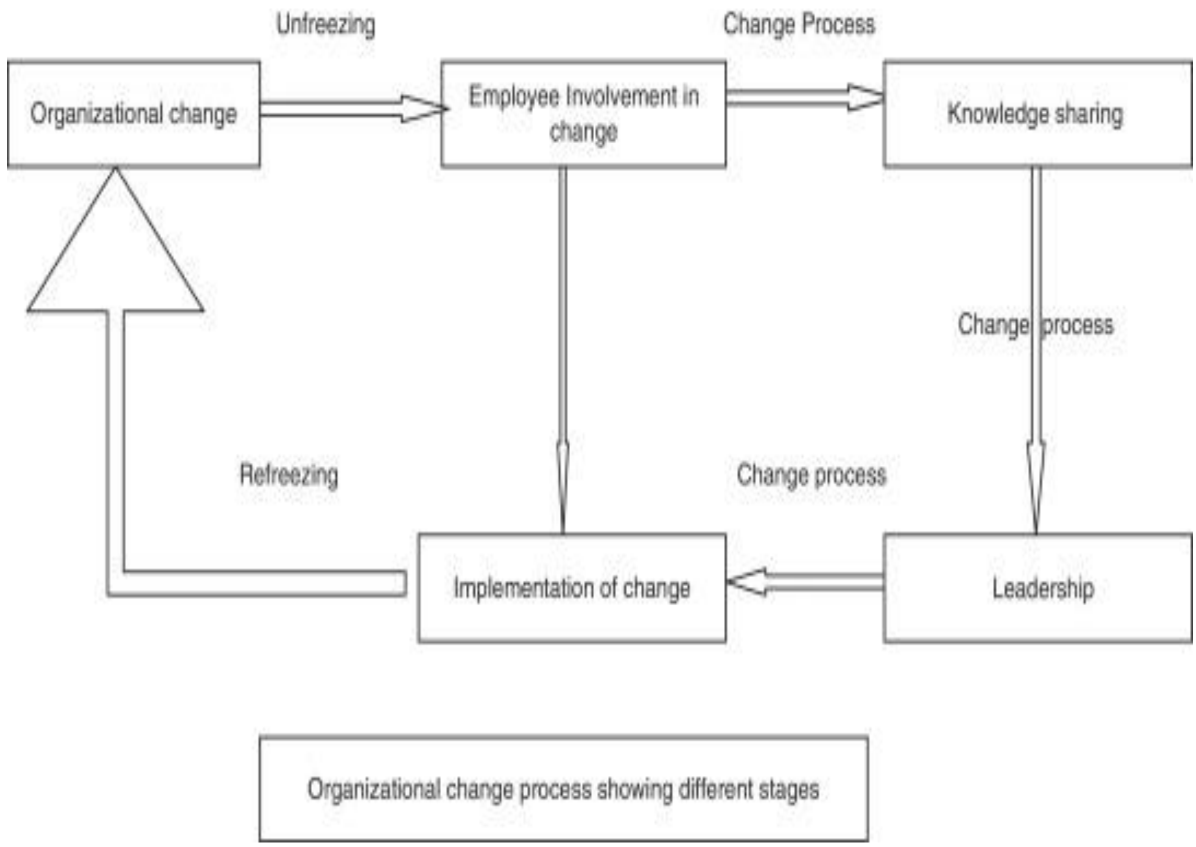

Figure 2.7: Model of organisational change shows Kurt Lewin's three steps model

Source: . (Bryman, 2018:126)

The arrows in Figure 2.7 show different stages of Kurt Lewin's three steps model and not the relationship between variables.

2.9.1 Unfreeze

Understanding the Current State

The first step in Lewin's model involves recognising the need for change within the organisation. For CSIR, this means acknowledging the existing gaps in knowledge management and the siloed work environment reported by software developers. The current state often reflects a lack of collaboration and communication among different teams, which can hinder innovation and problem-solving. Acknowledging these gaps is essential for initiating the change process.

To facilitate this understanding, CSIR must engage its employees in discussions that highlight the importance of knowledge sharing and the benefits of transitioning to a more collaborative culture. This awareness can be fostered through workshops, seminars, and informational sessions that elucidate how Industry 4.0 technologies can enhance productivity and efficiency. Research indicates that organisations that effectively communicate the need for change are more likely to succeed in their transformation efforts (Ghanam *et al.*, 2012).

Facilitating Readiness for Change

Creating a sense of urgency is critical in the unfreezing stage. Employees must understand the implications of remaining static in a rapidly evolving technological landscape. To effectively "unfreeze" the current state, CSIR should focus on several key strategies:

Training and Development Programmes: Engaging employees through training sessions that cover the advantages of adopting Industry 4.0 technologies and improved knowledge management practices is vital. For instance, workshops that introduce concepts such as cloud computing, data analytics, and artificial intelligence can prepare staff for the upcoming changes (Deloitte, 2016).

Leadership Engagement: Leadership plays a pivotal role in driving change. Leaders at CSIR should model the behaviours they wish to see in their teams. By demonstrating commitment to knowledge sharing and collaboration, they can inspire employees to embrace these values.

Open Communication Channels: Establishing open lines of communication allows for feedback and concerns to be voiced. This not only helps identify potential resistance to change but also fosters a culture of trust and transparency (Fomunyam, 2020).

Creating a Collaborative Environment

To further prepare for change, CSIR must work towards dismantling existing silos. Research shows that organisations often struggle with collaboration due to departmental boundaries that inhibit knowledge sharing (Motyl *et al.*, 2017). CSIR can implement strategies such as:

Interdisciplinary Teams: Forming teams that include members from various clusters can promote cross-pollination of ideas and skills. This approach not only enhances problem-solving but also facilitates a deeper understanding of different departmental challenges.

Collaborative Technologies: Introducing collaborative platforms, such as project management tools and communication software, can help bridge the gap between different teams. These technologies allow for real-time information sharing and collective problem-solving (Ivanov *et al.*, 2018).

2.9.2 Change

Implementing New Practices

The second step in Lewin's model involves the actual transition to new ways of working. For CSIR, this means implementing collaborative platforms and tools that facilitate knowledge sharing among software developers across different clusters. The implementation phase should focus on several key areas:

Training Programmes: CSIR should invest in comprehensive training programmes that equip software developers with the necessary technical skills to navigate Industry 4.0 technologies. These programmes should cover a wide range of topics, including emerging coding languages, data analytics, and AI, as well as soft skills essential for collaboration and effective communication (Kipper *et al.*, 2021).

Pilot Projects: Implementing pilot projects can serve as a testing ground for new practices. By starting small, CSIR can gather feedback and make necessary adjustments before a full rollout. This iterative approach allows for learning and adaptation, minimising resistance and enhancing buy-in from staff (Rashed *et al.*, 2023).

Feedback Mechanisms: Actively soliciting feedback from employees about the new initiatives and tools is essential during the change phase. CSIR should create structured channels for employees to voice their opinions and concerns. This participatory approach not only enhances the change process but also cultivates a sense of ownership and commitment among employees.

Encouraging Participation and Feedback

The success of the change phase relies heavily on employee engagement. CSIR should implement strategies to encourage participation, such as:

Workshops and Focus Groups: Hosting workshops and focus groups can provide employees with a platform to express their thoughts on new practices. These sessions can also be used to gather insights into potential challenges and areas for improvement.

Recognition Programmes: Recognising and rewarding employees who actively contribute to the change process can motivate others to engage. CSIR could implement a rewards system that acknowledges collaborative efforts and innovative contributions to knowledge management.

Monitoring Progress

Monitoring progress during the change phase is crucial. CSIR should establish key performance indicators (KPIs) to assess the effectiveness of new practices and technologies. Regular evaluations can help identify areas for improvement, ensuring that the organisation remains responsive to the evolving needs of its workforce (McKinsey Global Institute, 2021).

2.9.3 Refreeze

Solidifying the Changes

Once new practices are implemented, the final step is to “refreeze” the organisation to stabilise the new state. This involves reinforcing the changes made and ensuring they become part of the organisational culture. For CSIR, this could include:

Ongoing Training Programmes: Establishing continuous training programmes ensures that employees remain up to date with the latest Industry 4.0 technologies and practices. Regular workshops can reinforce the importance of knowledge sharing and collaboration.

Knowledge-Sharing Sessions: Regularly scheduled knowledge-sharing sessions can promote ongoing dialogue among employees. These sessions could involve presentations from different teams, showcasing their projects and the lessons learned.

Cultural Integration: To fully embed the changes into the organisational culture, CSIR should focus on integrating collaboration and knowledge sharing into its core values. This might involve revising the organisation’s mission statement or creating new policies that prioritise these practices.

Monitoring and Evaluation

To ensure that the changes are sustained, CSIR should implement mechanisms for monitoring and evaluating the effectiveness of the new knowledge management practices and collaborative tools. Frequent evaluations can highlight areas for enhancement and ensure that the organization stays attuned to the changing needs of its workforce. Feedback Loops: Establishing feedback loops allows for continuous input from employees on the effectiveness of new practices. This can be achieved through surveys, suggestion boxes, or regular check-ins.

Performance Metrics: CSIR should develop performance metrics to assess the impact of new practices on productivity and collaboration. These metrics can help identify successful initiatives and areas that require further attention.

Adaptation and Flexibility: The organisational landscape is constantly evolving, particularly in the context of Industry 4.0. CSIR must remain adaptable, and ready to refine and adjust practices in response to new challenges and opportunities (Ghobakhloo, 2020).

Lewin's Theory of Change provides a structured approach for CSIR to navigate the complexities of change as it adapts to the demands of Industry 4.0. By following the steps of unfreezing, changing, and refreezing, CSIR can effectively enhance its knowledge management practices and promote collaboration among software developers. This theoretical framework not only guides the implementation of change but also emphasises the importance of employee engagement and cultural transformation in achieving sustainable success.

In summary, as organisations such as CSIR strive to remain competitive in an increasingly digital landscape, leveraging frameworks such as Lewin's Theory of Change can facilitate a smoother transition and help cultivate a culture of continuous learning and collaboration. By focusing on these principles, CSIR can position itself as a leader in the adoption of Industry 4.0 technologies, ultimately driving innovation and improving organisational efficiency.

2.10 Summary

Technical skills are crucial for engineering graduates (World Economic Forum, 2016) and it is important for students to empower and equip themselves with soft skills, as technical expertise cannot function in isolation. Soft skills mostly refer to English proficiency and communication skills. Both categories of skills are very significant for graduates to secure early employment in the era of Industry 4.0. Technical skills are essential for university graduates because they address the needs of Industry 4.0; hence, the combination of soft and technical skills will be sought by employers in the future (Ghobakhloo, 2020).

Jelonek *et al.* (2020) state that technical skills need to be enhanced through more learning and practice, as future graduates need to master various skills, knowledge and capabilities in order to challenge the Industry 4.0 environment. According to Matturo *et al.* (2019), the industrial training programmes that existed before Industry 4.0 are irrelevant and provide no basis for the skills required for future jobs. Therefore, the education sector should embed technical and soft skills into training programmes in order for such programmes to become relevant and to support the Industry 4.0 environment.

Lack of adequate work experience is a challenge for Industry 4.0 employers (Melissa *et al.*, 2020). Graduates should participate in learnerships and graduate programmes before entering the professional work environment. Foundational training programmes with Industry 4.0 elements are the basis for reducing the unemployment rate in South Africa (Department of Trade and Industry, 2017). The development of graduates should empower and equip them to be competent and meet the demands of Industry 4.0. The significant gap existing between graduate employment readiness and employers' skills expectations should be addressed through relevant training programmes and adjustment of curricula.

CHAPTER 3 – METHODOLOGY

3.1 Research approach

This study employed a qualitative research design to explore the workforce readiness of software developers at the Council for Scientific and Industrial Research (CSIR) in the context of the Fourth Industrial Revolution (4IR). The qualitative approach was chosen to obtain a deeper understanding of the experiences, perceptions, and abilities of software developers, emphasizing both their technical and soft skills, along with the organizational challenges they encountered.

A qualitative approach was employed for this study, driven by several key factors. First, qualitative methods provide a rich and nuanced understanding of participants' experiences and perceptions, which is crucial for exploring the intricate dynamics of software development in the context of Industry 4.0. Unlike quantitative research, which often prioritises numerical data and statistical analysis, qualitative research focuses on the meanings and interpretations that individuals attach to their experiences. This depth of understanding is essential when investigating the preparedness of software developers, as it allows for a more comprehensive exploration of their skills, challenges, and aspirations considering emerging industrial demands (Akbar *et al.*, 2020).

The qualitative approach is particularly well-suited for examining complex social phenomena where context matters. In the case of Industry 4.0, the rapid technological advancements and evolving skill requirements create a landscape that is inherently complex and multifaceted. A qualitative approach enables the researcher to capture the subjective realities of software developers, providing insights into how they perceive and respond to these changes. This perspective is vital for identifying gaps in skills and training that need to be addressed to enhance readiness for the Fourth Industrial Revolution (Motyl *et al.*, 2017).

3.2 Sampling and participants

In this study, a purposive sampling technique was utilised to select participants, ensuring that the sample was both relevant and informative regarding the research objectives. The focus on purposive sampling allowed for the deliberate selection of individuals who possess specific characteristics and experiences that align with the study's goals. Specifically, the sample comprised 15 software developers employed at the CSIR. This number was strategically chosen to facilitate an in-depth exploration of their perspectives while remaining manageable within the constraints of the study's timeframe and available resources.

The rationale behind selecting software developers from the CSIR was twofold. First, the CSIR is a prominent research institution in South Africa, known for its contributions to technological innovation and development, particularly in the context of Industry 4.0 (CSIR, 2024). By focusing on participants within this organisation, the study aimed to gather insights from individuals who are at the forefront of software development projects that leverage emerging technologies relevant to the Fourth Industrial Revolution (4IR). Their involvement in such projects positions them uniquely to provide valuable perspectives on the challenges and opportunities associated with the integration of 4IR technologies into software development practices.

Secondly, the selection criteria for participants included their experience and expertise in software development related to 4IR technologies. This emphasis on relevant experience was crucial for ensuring that the insights gathered would be meaningful and applicable to the broader discourse on the implications of 4IR in the software development sector. According to (Smith, 2020), the successful implementation of Industry 4.0 technologies necessitates a deep understanding of both technical and contextual factors; thus, participants with hands-on experience were deemed essential for the study.

The decision to limit the sample size to 15 participants was informed by the need for a balance between depth and breadth of data collection. A smaller sample allows for more comprehensive interviews, enabling the researcher to explore participants' thoughts, feelings, and experiences in greater detail (Creswell, 2020). This depth is particularly important in qualitative research, where the richness of data can provide nuanced insights into complex phenomena such as the adaptation to and implementation of 4IR technologies in software development.

Moreover, the study's design acknowledged the importance of diversity within the participant group. While all participants were software developers, efforts were made to include individuals with varying levels of experience, roles, and specialisations within the CSIR. This diversity enriches the data collected, as it captures a spectrum of perspectives and experiences, thus providing a more comprehensive understanding of the topic at hand. Research indicates that diverse teams can enhance creativity and problem-solving capabilities, which are crucial in the fast-evolving landscape of 4IR technologies (Ghobakhloo, 2020).

3.3 Data collection

In this study, semi-structured interviews served as the primary method of data collection, allowing for an in-depth exploration of participants' perspectives regarding their readiness for the Fourth Industrial Revolution (4IR). This qualitative approach was chosen for its ability to facilitate open dialogue while maintaining a focus on specific research questions. The researcher developed a set of interview questions designed to probe into various dimensions of the participants' experiences, including their technical and soft skills, readiness for 4IR, and the challenges they faced in adapting to the rapidly evolving technological landscape.

The semi-structured format of the interviews provided a balance between guided questioning and the flexibility to explore topics in greater depth. This adaptability is particularly important in qualitative research, as it allows the researcher to follow up on intriguing or unexpected responses, thereby enriching the data collected (Leedy & Ormrod, 2015). While the interview guide ensured that all key topics were consistently covered across interviews, the open-ended nature of the questions encouraged participants to share their thoughts and experiences in their own words, which can lead to more nuanced insights.

The interview guide encompassed the following key themes, each aimed at addressing critical aspects of the participants' experiences:

First, understanding of 4IR and Implications for Software Development: Participants were asked to articulate their understanding of the Fourth Industrial Revolution and how they perceive its implications for their work in software development. This theme aimed to gauge the level of awareness and comprehension of 4IR concepts among developers, as well as the perceived relevance of these concepts to their daily tasks.

Secondly, self-assessment of Technical and Soft Skills: The second theme focused on participants' self-assessment of their technical and soft skills pertinent to 4IR technologies. This included enquiries about specific programming languages, tools, and frameworks, as well as interpersonal skills such as communication, teamwork, and adaptability. Understanding how developers perceive their own skill sets is crucial for identifying areas where additional training or development may be necessary.

Thirdly, perceived Challenges and Opportunities: Participants were encouraged to discuss the challenges they encountered while adapting to the demands of 4IR, as well as any opportunities they identified in this evolving landscape. This theme aimed to uncover the barriers to successful adaptation, such as knowledge gaps or organisational resistance, while also highlighting potential avenues for growth and innovation within the field.

Lastly, organisational Support and Resources: The final theme explored the nature and extent of organisational support available for skill development and readiness in the context of 4IR. Participants were asked to reflect on the resources, training programmes, and mentorship opportunities provided by their employer, as well as their perceptions of how these supports impact their ability to adapt to new technologies.

Each interview lasted approximately 45 to 60 minutes. The interviews were conducted using Microsoft Teams (MS Teams), a widely used digital communication platform that facilitates virtual meetings and collaboration. This choice of medium offered several advantages for the research study.

According to Purba (2021), the advantages of using MS Teams for interviews are as follows:

- Accessibility: MS Teams allows participants to join meetings from various locations, eliminating geographical barriers. This is particularly beneficial for a diverse group of software developers who may be situated in different offices or even working remotely.
- Convenience: Scheduling interviews via MS Teams can be more flexible compared to in-person meetings. Participants can join from their own environments, which may help them feel more comfortable and open during the interview.
- Recording Features: MS Teams provides built-in options for recording meetings, ensuring that the researcher can capture the conversation accurately. This is essential for later transcription and analysis of the interviews.

Visual and Audio Interaction: The platform supports both video and audio communication, allowing for a more engaging interaction. Participants can share non-verbal cues through video, which can enhance the richness of the data collected.

Chat and File Sharing: During the interviews, MS Teams allows for real-time chat and document sharing. If clarification is needed on specific topics or if participants wish to refer to relevant materials, they can do so instantly.

Confidentiality and Security: MS Teams provides a secure environment for conducting interviews, which is crucial for protecting participants' confidentiality. The platform's security features help ensure that sensitive information is safeguarded.

By using MS Teams, the researcher was able to conduct effective and efficient interviews, capturing valuable insights while accommodating the participants' circumstances and preferences.

This careful consideration of the interview environment was crucial for encouraging participants to share their genuine thoughts and feelings without fear of judgement or repercussions. To ensure accuracy in data collection, the interviews were audio-recorded with the participants' consent. The recordings were subsequently transcribed verbatim, creating a rich dataset for analysis.

The transcriptions provided a comprehensive account of the participants' responses, allowing for a detailed thematic analysis. This method of data collection not only enabled a deep dive into the individual experiences of software developers but also facilitated the identification of common themes and patterns across interviews (Bryman, 2020). Ultimately, the semi-structured interviews were instrumental in capturing the complexities of participants' experiences and perceptions regarding their readiness for the Fourth Industrial Revolution, contributing valuable insights to the research field.

3.4 Data analysis

In this study, thematic analysis was employed as the primary method for analysing the interview data. Thematic analysis is a widely used qualitative analysis method that focuses on identifying, analysing, and reporting patterns (themes) within qualitative data. This approach is particularly well-suited for exploring complex phenomena such as workforce readiness, as it allows for a rich understanding of participants' experiences and perspectives (Smith, 2020).

The first step in the thematic analysis process involved the researcher familiarising themselves with the data. This was achieved through repeated readings of the interview transcripts, which enabled the researcher to immerse themselves in the content and gain a comprehensive understanding of the participants' responses. According to Creswell (2020), this initial step is crucial because it lays the groundwork for subsequent analysis by helping the researcher identify key ideas and distinctions in the participants' narratives.

Following the familiarisation phase, the researcher moved on to coding the transcripts. Coding is a fundamental aspect of thematic analysis, where significant statements, phrases, or sentences are highlighted and labelled with codes that capture their meaning. For this study, the researcher developed a coding framework that included both descriptive and interpretative codes (Smith, 2020). Descriptive codes captured the surface-level content of participants' responses, while interpretative codes aimed to convey deeper meanings, insights, or implications related to workforce readiness in the context of 4IR. During this phase, the researcher remained attentive to both expected themes, based on the interview guide, and emergent themes that arose organically from the data. This dual approach ensured a comprehensive understanding of the participants' experiences, allowing for a more nuanced analysis that could reveal unexpected insights.

Once the coding was completed, the researcher began to identify patterns and themes within the coded data. This involved collating all relevant coded data extracts into potential themes, which were then reviewed to assess their relevance and coherence. The process of identifying themes is iterative and often requires multiple rounds of review to ensure that the themes accurately reflect the data (Johnson & Onwuegbuzie, 2020). The researcher sought to group related codes into broader themes that encapsulated the essence of participants' experiences and perceptions regarding their readiness for 4IR. For instance, themes might emerge around self-assessment of skills, perceived challenges in adapting to technological advancements, and the role of organisational support in facilitating skill development. By clustering codes into thematic categories, the researcher was able to construct a comprehensive narrative that captured the complexities of workforce readiness (Creswell, 2020).

The identified themes underwent a thorough review and refinement process to ensure they accurately represented the data and addressed the research aims. This involved considering whether each theme was supported by sufficient data extracts and whether the themes collectively provided a coherent understanding of the research topic. The researcher also sought feedback from the supervisor to enhance the credibility of the thematic framework. This external perspective can offer valuable insights and help identify any potential biases or gaps in the analysis (Tashakkori & Teddlie, 2020).

Through this iterative process of reviewing and refining, the final themes were crystallised, providing a solid foundation for interpretation and discussion. The themes were not only aligned with the research objectives but also offered an in-depth exploration of the factors influencing workforce readiness in the context of 4IR.

3.5 Trustworthiness

Trustworthiness in qualitative research is crucial for establishing the credibility, transferability, dependability, and confirmability of the study's findings (Bryman, 2020). The following were the strategies employed in this research to ensure the trustworthiness of the data gathered and the conclusions drawn.

Credibility

Credibility refers to the confidence in the truth of the findings. To enhance credibility, this study employed several strategies:

After the interviews were conducted and transcribed, participants were invited to review their responses for accuracy and clarity. This process allowed participants to confirm that their views were accurately represented and provided opportunities to refine or elaborate on their statements, thus enhancing the authenticity of the data.

Although the primary data collection method was semi-structured interviews, triangulation was achieved by comparing the interview data with existing literature on Industry 4.0 and workforce readiness. This comparison helped to corroborate findings and provided a more comprehensive understanding of the challenges faced by software developers in adapting to new technologies.

Transferability

Transferability pertains to the extent to which findings can be applied in other contexts. To support transferability, the study provided detailed descriptions of the research context, participant demographics, and the processes involved in data collection and analysis. This rich contextual information allows other researchers and practitioners to assess the relevance of the findings to their own settings (Johnson & Onwuegbuzie, 2020).

Additionally, the specific focus on software developers at CSIR, a key player in technological innovation in South Africa, provides insights that may be applicable to similar research contexts or organisations facing the challenges of 4IR.

Dependability

Dependability refers to the stability of data over time and under different conditions. To ensure dependability, an audit trail was maintained throughout the research process. This included detailed documentation of the research design, data collection methods, coding processes, and thematic analysis (Smith, 2020). By providing a clear record of the research steps taken, future researchers can follow the same procedures, allowing for an assessment of the study's reliability.

Furthermore, peer debriefing was utilised, wherein colleagues knowledgeable about qualitative research methods reviewed the study's design, data collection, and analysis procedures. Their feedback helped to identify potential biases and inconsistencies, enhancing the robustness of the findings.

Confirmability

Confirmability addresses the neutrality of the findings and the extent to which they are shaped by participants rather than the researcher's biases. To enhance confirmability, the researcher engaged in reflexivity throughout the research process (Creswell, 2020). This involved reflecting on personal biases, assumptions, and potential influences on the research outcomes. Keeping a reflexive journal allowed the researcher to document thoughts and feelings about the data collection and analysis, helping to minimise bias.

Additionally, participants were encouraged to express their views freely, and efforts were made to create a supportive interview environment, fostering open communication. The researcher's commitment to presenting participants' perspectives as authentically as possible contributed to the confirmability of the study's findings (American Psychology Association, 2020).

3.6 Ethical consideration

The Council for Scientific and Industrial Research facilitated access to participants by providing a gatekeeper's letter to the researcher, who conducted the interviews for the study. Participants were given informed consent forms to sign prior to their involvement. The interviews were conducted and recorded using MS Teams. The author has affirmed compliance with the ethical standards set forth by the University of KwaZulu-Natal's Code of Research Ethics and Policy principles for responsible research. This commitment underscores the importance of acting ethically throughout the processes of data collection, analysis, and interpretation.

CHAPTER 4 – FINDINGS AND ANALYSIS

This chapter presents the research findings preceding the analysis of the data. The findings were an outcome of the data collection process. Interviews with software developers were conducted and the findings are discussed in this chapter.

4.1 Research questions

Interviews were conducted with 15 software developers at CSIR. The following sections mirror questions asked to participants on the questionnaire. (See Appendices for the questionnaire provided to participants).

4.1.1 How would software developers adapt their skills training to address the requirements of Industry 4.0 in the future?

CSIR is in pursuit of adopting Industry 4.0 technologies, and this has been driven by changes in technological advances (Doermann, 2024). Participants acknowledged that software development is constantly changing and that for them to adapt their skills, they need to embark on continuous learning through various online platforms such as Udemy and LinkedIn Learning and attend prescribed training sessions in order to align their skills with Industry 4.0 demands. Responses included emphasis on active learning through various online platforms and collaborative engagements with their peers as they believed that learning from others can enhance their existing skills (upskilling).

For instance, one participant said he felt the need to be trained in order to address the needs of the Industry 4.0skills set. He also felt that collaborative platforms should be implemented. He noted that software developers should be proficient in emerging technologies such as artificial intelligence, Internet of Things and machine learning. He said, “Umm, I think as we are in this, the ICT space which is which is a which is growing so fast and the only way to keep up the with the industry in the ICT to always.”

Another participant emphasised the point of training and encouraged collaboration with other disciplines. There was a strong emphasis for software developers to familiarise themselves with cloud platforms and he said, “Umm, in terms of adapting skills, uh yeah, for it will be to learn the technologies and from Marelize myself with the development technologies and frameworks that I used in some industrial out, say in robotics for example in that area, I think out need there.”

4.1.2 How do you keep abreast of changes in the software development field?

One respondent recommended that CSIR needs to provide ongoing education that involves reskilling and upskilling. There was a collective view that CSIR needs to invest in digital infrastructure to adopt emerging technologies such as cloud computing, cybersecurity, and data analytics. Some respondents recommended that CSIR automate processes to ensure a continuous flow of updated data information. Generally, the respondents felt strongly that CSIR should plan ahead to facilitate transition to a digital state and that this could be achieved through understanding the human aspect and communicating organisational goals.

For instance, one participant said that regularly participating in courses on platforms like Coursera, Udemy, or edX helps stay updated on new technologies and methodologies. Joining online communities (such as Stack Overflow, GitHub, or Reddit) allows for interaction with other developers and exposure to diverse perspectives. Staying updated with newly published books on software development can provide in-depth knowledge on specific topics. One respondent said, “The reality of it is that the more things change, the more they stay the same” and went further to say, “There’s things which are brand new, so the only thing is to just assess how things are being done currently, so they learning new things, and reviewing how things are being done”.

Another participant said: Encourage that software developers should attend industry conferences, workshops, and local meetings to foster networking and learning about the latest tools and practices. The respondent said, “So it’s always a good for as a young researcher to know what is out there and what can we provide for industry” and mentioned “, So most of the time I’ll find myself being on YouTube and going through what others are saying within our space”.

Responses included the inability to solve complex problems, which largely depended on the emerging coding languages that Industry 4.0 has introduced, as well as understanding requirements and struggling with adopting coding environments. One of the respondents stressed the difficulty of adapting to new technology. Overall, respondents felt strongly that they should be trained in soft skills as these would allow them to collaborate with others and eliminate discomfort when presenting in front of groups. There was strong discouragement of working in silos, but rather that software developers should learn to delegate tasks among themselves, which would encourage continuous learning. Another respondent stated that they overcommit to tasks to be performed.

Most of the respondents were satisfied with their current skills and were encouraged that CSIR was already embracing Industry 4.0 and its demands. Some respondents stated that they would like more training on artificial intelligence and robotics because they acknowledged that Industry 4.0 eliminates the use of human beings and that machines would perform tasks. One respondent believed that the human element would still be needed in an Industry 4.0 environment as machines would need to be maintained.

4.1.3 What are the current skills software developers need to operate at CSIR (As-Is)?

Most software developers were initially employed at CSIR for internship roles, even though they were in ICT. They acknowledged that they had grown through the ranks within the ICT environment as software developers and strongly believed that their current roles aligned with their job expectations. Some respondents were employed at CSIR as experienced software developers, and they simply answered "Yes" to the question. All the respondents did not fully agree with the question; however, their emphasis was more on continuous learning through various ICT online platforms, eBooks, journals and attending virtual training if made available to them.

For instance, one participant said: There is a strong belief in programming languages such as Java, C++, Python, and JavaScript, which are essential for developing applications and systems and also languages around database management such as SQL and NoSQL databases for data storage and retrieval. One respondent said, "For me, honestly and truly speaking, it is uh, mostly. My Java. And C++ the they" and also stressed the difficulty of coding by saying, "A coding stuff, but it is not as intense as I would like it to be, you know, so there's a lot of learning that I still need to get".

Another participant said: Generally, gaining familiarity with software development tools such as Agile, Scrum, and Waterfall methodologies helped developers manage projects efficiently. Skills in automated testing frameworks and debugging tools were vital for ensuring software quality. The respondent said, "So as a research institution or and and the nature of work that we are doing, uh, you don't necessarily work on one thing for a extended periods or four years each and every year there will be new their project with with new skills requirements which yeah have learned to adapt to over there".

There was consensus that they aspired to improve their skills because the skills that they possessed were not aligned with Industry 4.0 requirements. One respondent stated that they were not familiar with project reporting tools currently being used, such as Confluence and Jira. Generally, respondents were not sure what skills to improve on, but given a chance to understand their skills in relation to the demands of Industry 4.0, they would be willing to improve their skills to align with Industry 4.0.

For instance, one participant said: To determine which skills you want to improve or acquire. Be specific about your goals to focus your efforts on and consistent practice is key. Dedicate time each week to work on exercises, projects, or simulations related to the skills you wish to develop. One respondent said, "You also do that by, you know, continuously improving your skills". While the other reaffirmed that developers need to develop a structured plan that outlines the resources, courses, and timelines you will use to achieve your goals and utilise various resources such as online courses, tutorials, books, and articles that align with your learning objectives. The other respondent said, "Uh, it's more moving towards the, I mean, you know, AI and data science, the data science field."

The consensus from senior software developers was "Yes"; however, they believed that continuous learning and training would assist them to master certain skills required for Industry 4.0. Most junior software developers believed that they needed more exposure by getting involved in Industry 4.0 projects to enhance their skills, as well as encouragement to work on cross-cutting projects so that they could learn from experienced developers.

For instance, one participant said: Regular learning helps keep your skills up to date, ensuring you remain competitive in your field. Continuous learning fosters adaptability, allowing you to navigate changes in technology and industry trends more effectively and gaining new knowledge and skills boosts self-confidence, making you more willing to take on challenges. One respondent said, "Definitely yes, but mostly do online". And went further to say "You know all I courses through you, Demi."

Another participant said: Acquiring new skills can lead to promotions, new job opportunities, and greater earning potential. The respondent emphasised that developers need to familiarise themselves with Industry 4.0 and said this “New technology within fourth industrial revolution environment”.

Responses included that software developers should work virtually as they did not need to be physically present at work. This would promote flexible working hours and eliminate disturbances. Respondents suggested avoiding unnecessary meetings as they deemed this a waste of time and train-the-trainer programmes that could avoid a shortage of skills in case there was a huge software developer turnover. Respondents felt that they received adequate support from their line managers.

4.1.4 What are gaps to be addressed to equip software developers to operate in an Industry 4.0 environment (To-Be)?

Responses on continuous learning and training, attending seminars and conferences were also strongly supported. The introduction of knowledge-sharing sessions was encouraged as a platform to learn from other projects’ achievements and failures. In terms of training and development, there was a strong emphasis on the coding languages used in Industry 4.0, such as Python, artificial intelligence, C++ and DevOps, to enhance their knowledge and experience. Participation in more projects and cross-cutting initiatives to gain more experience was also mentioned.

There was a strong emphasis on Industry 4.0 coding languages, as well as the need to improve on soft skills such communication and being creative. The view was expressed that although there would be job uncertainty there was a strong belief that software developers would develop in terms of programming machines and that maintaining those machines at the back end would still require developers. Generally, the view was that they might not be much involved in the front end of those machines but that their skills would be needed in Industry 4.0 software development environments. Views expressed were that more training should be provided, learning should be encouraged through various online platforms, and that more research should be conducted in their own areas of work.

For instance, one participant noted that developers need a solid understanding of Internet of Things (IoT) technologies, including protocols, sensors, and data management, to integrate smart devices into applications. Proficiency in data analytics and data science is crucial. Developers should learn how to analyse and interpret large datasets to drive insights and decision-making. The respondent said, “Ohm and so I mean I do have some data science skills, but I would think I would say that there’s not a lot for me to learn” and the other said, “I guess services will still be needed because the 4R is being driven by software development and”

4.1.5 What is the state of readiness for Industry 4.0 among software developers at CSIR?

Respondents felt that CSIR was doing enough to support them because it funded training and online subscriptions so they could keep abreast of the latest developments within the ICT space in general. Respondents felt that they were ready for Industry 4.0. The view was that CSIR was already providing them with support to face the challenges and demands of Industry 4.0. The human capital unit at CSIR encouraged those who wanted to explore or embark on digital training programmes, and respondents supported and encouraged this.

For instance, one participant said: Developers at CSIR are likely equipped with foundational programming skills and experience in various software development methodologies. However, readiness for Industry 4.0 may vary depending on individual expertise in emerging technologies such as IoT, AI, and data analytics. The availability of resources such as tools, platforms, and technology for experimentation and development is crucial for fostering readiness. CSIR’s access to the latest technologies can enhance developers’ preparedness. Involvement in projects that utilise Industry 4.0 technologies can provide practical experience. The extent of such projects at CSIR can indicate the readiness level. One respondent said, “Because companies employed people who are actively growing and learning on their own.” and further mentioned the use of online tools “The Free Udemy and the Free LinkedIn learning”.

Another participant said: CSIR may have initiatives in place to provide training and upskilling opportunities for developers. The effectiveness and frequency of these programmes can significantly impact readiness. Collaboration between software developers and professionals from other fields (engineering, data science, etc.) is essential for understanding the broader applications of Industry 4.0 technologies. CSIR's focus on research and innovation can contribute to a proactive approach in adopting Industry 4.0 practices, encouraging developers to stay ahead of trends.

The respondent said, "So before I implement something I they're home adequate research"

Most respondents agreed that CSIR was ready because of its developments and initiatives that aligned with Industry 4.0. Some respondents felt that CSIR was not ready as there were still manual processes and activities that should have been transitioned to online processes. One respondent provided an example of the manual declaration of laptops at entrance gates. Another respondent suggested that asset verification should be fully online rather than physical verification of assets at the office.

Most respondents identified with a score of 8 because CSIR had gone far with the latest technology infrastructure to boost innovation and address Industry 4.0 needs. Some respondents scored 2, as they felt that even if the infrastructure existed, the CSIR was not yet 100% digital. Respondents felt that SIR did not recognise them adequately, that career growth was made difficult for them, and that they were treated as employees in a support role rather than as professionals. They encouraged the CSIR to look at this issue, and respondents strongly suggested improved collaborative platforms and encouraged research and development. Responses included that CSIR leadership should review the reward system for software developers, motivate junior developers by offering mentorship programmes, and encourage content repurposing.

4.2 Theme identification and discussion

The following themes (Table 4.1) were identified from the findings described above.

Table 4.1: Themes and emotions emerging from interviews

Themes and Emotions	Occurrence (Out of 15)	Question
Training	8	Willingness to adapt their skills?
Collaboration	9	How do develop yourself for the future?
Reskilling	7	What has changed?
Problem-solving	6	What are your weaknesses?
Continuous learning	9	How to change for the future?
Internships	4	What was your job description?
Innovation	7	What are Industry 4.0 demands?
Upskilling	7	Are you willing to learn for the future?
Happiness	6	Do you have adequate skills?
Hybrid working	7	What can you change?
Knowledge sharing	6	How do you keep abreast of emerging technologies?
Inclusion and participation	7	How do you need reskilling and upskilling?
Coding	2	What are key areas of improvement?
Thankful, appreciation	8	What is the future of software developers in Industry 4.0?

Themes and Emotions	Occurrence (Out of 15)	Question
Seminars	6	Where do you need assistance?
Excitement	10	How is the CSIR supporting you?
Satisfaction	12	Are you ready for Industry 4.0?
Appreciation	9	Is the CSIR ready for Industry 4.0?
Career growth	10	What to change at CSIR?
Helping others	11	What can CSIR do to ensure successful integration to Industry 4.0
Mentorship	7	What is it the CSIR needs to improve on?

4.2.1 Training and reskilling

This was a prominent theme emanating from the software developers' responses. They stated that there was a great deal to be done in order for CSIR to be on par with developments of Industry 4.0 and to remain competitive. The introduction of new technologies and processes could create a shift in how the CSIR operated, hence the need for training and reskilling to retain software developers. This theme was deemed highly necessary, and it was suggested that large investments be devoted to it because it would demonstrate to employees that CSIR was committed to their growth and development.

Views were expressed that Industry 4.0 was constantly changing and that CSIR needs to adapt to these changes to ensure that software developers are equipped with the necessary skills to be on par with new technologies and processes as they emerge. Training software developers can also foster a culture of innovation, which can improve efficiency and processes. Redundancy, which often emanates from not fully utilising developers, and resulting in high staff turnover, was also addressed. Some developers had left CSIR to seek opportunities elsewhere because they felt that their skills were stagnating.

4.2.2 Continuous learning

The respondents were grateful for what CSIR was doing for them. There was a strong sense that CSIR invested in e-learning programmes. Some respondents were pleased that CSIR was paying for their subscription to online programmes (LinkedIn Learning and Udemy) to keep up with emerging technologies. One respondent also stated that CSIR should encourage developers to further their studies beyond bachelor's degrees because technology is constantly changing, which they termed "investing in lifelong learning". Lifelong learning creates awareness about new developments, challenges, and trends in the software development environment.

There was strong emphasis on the need for software developers to improve on their soft skills such as communication, leadership and decision-making. One respondent indicated that most software developers tend to work in silos and stressed that in Industry 4.0, collaboration networks and platforms should be encouraged because this would improve their skills and encourage continuous learning.

4.2.3 Process improvement

There was a suggestion that CSIR should review its processes to address Industry 4.0 challenges and demands. As technology constantly evolves, there is a great need to improve processes to allow for efficiency and sustainability. Some respondents stated that CSIR was moving towards addressing Industry 4.0 demands but that it had not fully integrated its processes. This was an indication that even though some processes were automated, there was a great deal of improvement in manual processes.

Developers mentioned that CSR needs to improve its collaborative design platforms to allow teams across projects to share and access Industry 4.0 insights. One respondent suggested that the manual asset verification process was outdated and recommended that the CSIR should be using the IoT to monitor and verify assets in real time. There was a strong acknowledgement that CSIR was geared towards

Industry 4.0 needs; however, it had not fully automated its processes. Process automation reduces human error and saves time.

4.2.4 Leadership style

There was a recommendation that CSIR should move away from traditional management styles. It was suggested that non-digital managers should be trained in line with the needs of the digital environment. Software developers felt that their profession was not yet recognised as professional but rather classified as support. They questioned why they were considered support staff if they provided software development services to CSIR external clients and CSIR generates income from that service.

They suggested that digital leaders in some organisations recognised the competence and intelligence of software developers. Technology companies especially recognise them as professionals, and some implement reward systems as motivation. This has been deemed lacking at CSIR. Overall, they wanted the CSIR to train all traditional managers towards digital leadership and demanded to be recognised as professionals and be rewarded according to their expertise.

4.2.5 Knowledge sharing

Respondents encouraged the CSIR to introduce knowledge-sharing sessions where lessons learned from other projects are shared to encourage learning from other developers' experiences. Inclusion and participation in cross-cutting projects were also encouraged. Currently, at CSIR, software developers can only work in the department where they are employed. The software developers who participated in this study recommended that cross-cutting employment should be encouraged and supported to enable developers to learn about emerging technologies from other projects and engage in skills transfer. There are various platforms to achieve knowledge sharing, such as intelligent and cognitive computing.

CHAPTER 5 – RECOMMENDATIONS AND CONCLUSION

5.1 Introduction

This chapter presents the proposed recommendations emanating from the findings of the research, as well as recommendations for future research. As the study draws to its conclusion, it is useful to restate the aim, objectives and the primary and secondary research questions of the study to analyse whether they have been achieved and answered.

The aim of this study was to investigate the readiness of CSIR software developers for Industry 4.0. This would assist CSIR to explore possible areas of improvement to address the demands and challenges of Industry 4.0.

The following were the objectives of the study:

- To investigate the state of readiness for Industry 4.0 among software developers in CSIR.
- To determine the skill sets required for software developers within CSIR to deliver Industry 4.0 products.
- To establish the views of software developers and their needs for future Industry 4.0 products within CSIR.
- To understand the training required to prepare software developers for future Industry 4.0 demands within CSIR.

The primary research question for this study was the following:

What is the state of readiness for Industry 4.0 among software developers at CSIR?

The following sub-questions were explored:

- What are the current skills requirements that software developers need to operate at CSIR?
- What are the gaps to be addressed to equip software developers to operate in an Industry 4.0 environment?
- How should software developers adapt their skills training to address future requirements of Industry 4.0?

5.2 Recommendations for scientific research institutes

Based on the findings of this research, the following recommendations are proposed.

- Online Learning Platforms: Encourage developers to utilise platforms **such as** Udemy and LinkedIn Learning for relevant courses on emerging technologies (e.g., AI, robotics, cloud computing).
- Prescribed Training Sessions: Implement regular training workshops focused on Industry 4.0 technologies and soft skills, ensuring that developers are kept up to date with the latest advancements.
- Investment in Digital Infrastructure: The institutes should invest in robust digital infrastructure that supports cloud computing, cybersecurity, and data analytics, enabling developers to work effectively with these technologies.
- Soft Skills Development: Implement focused training on soft skills such as communication, teamwork, and presentation skills to help developers work effectively in teams and present ideas confidently.
- Leadership and Support: Ensure that line managers provide adequate support and resources for continuous learning and professional development.

5.3 Recommendations for future research

Based on the findings of this study, the researcher recommends that future researchers conduct an in-depth analysis on knowledge management as a key component to knowledge sharing, learning and transfer. Knowledge management in Industry 4.0 can enable staff to realise company goals and promote efficiency. It is evident that knowledge management is not fully applied at CSIR because there was a large contingent of respondents who stated that software developers at CSIR worked in silos. There are no internal collaborative platforms to engage with peers from other clusters and share knowledge and experience of projects that they have been involved in. To encourage learning, sharing and transfer of knowledge, the knowledge management component should be investigated at CSIR.

It is recommended that future researchers conduct longitudinal studies to track the effectiveness of continuous learning initiatives over time. This can help assess how ongoing education impacts developers' skills and adaptability to Industry 4.0 technologies.

Another recommendation is that future researchers should investigate the specific skills that are most critical for success in Industry 4.0. This includes both technical skills (e.g., emerging coding languages, AI, and data analytics) and soft skills (e.g., communication and teamwork).

5.4 Conclusion

Software development provides a fundamental foundation for Industry 4.0, and it is imperative that software developers strive to develop the systems necessary for automation, data analysis and connectivity. It allows organisations to promote efficiency, drive new business models and innovation. Software developers are enablers for developing reliable, scalable systems that drive automation and data-driven solutions. CSIR needs to leverage software developers' expertise in order to unlock positive outcomes of digital transformation.

Collaboration across various cross-cutting projects within the CSIR system through knowledge sharing and transfer by bringing together expertise and various perspectives can lead to robust, effective and innovative solutions. CSIR needs to encourage learning through structured training and learning programmes to address various aspects of software development.

Process re-engineering and continuous learning programmes are necessary to address Industry 4.0 demands and challenges. Soft skills programmes need to be introduced to help software developers familiarise themselves with the concept of Industry 4.0. More than half of the respondents were familiar with Industry 4.0 concepts and their implementation at CSIR.

CHAPTER 6 – REFERENCES

1. African Union, 2019.The digital transformation strategy for Africa (2020-2030). Addis Ababa: African Union.
2. Akbar, M.A., Sang, J., Nasrullah, Khan, A.A., Mahmood, S., Qadri, S.F., Hu, H. and Xiang, H., 2019. ‘Success factors influencing requirements change management process in global software development’, Journal of Computer Languages, 51, pp. 112-130 https://www.sciencedirect.com/science/article/abs/pii/S1045926X18301411 (22 September 2023).
3. Alcácer, V. and Cruz-Machado, V., 2019. ‘Scanning the Industry 4.0: a literature review on technologies for manufacturing systems’, Engineering Science and Technology, an International Journal, 22(3), pp. 899-919. [Online] Available at: https://www.sciencedirect.com/science/article/pii/S2215098618317750 (20 September 2023).
4. Beier, G., Ullrich, A., Niehoff, S., Reißig, M. and Habich, M.,2020. ‘Industry 4.0: How it is defined from a sociotechnical perspective and how much sustainability it includes – a literature review’, Journal of Cleaner Production, 259. [Online] Available https://www.sciencedirect.com/science/article/pii/S0959652620309033 (15 October 2023).
5. Bryman, A., 2020. Social research methods. 5th edn. Oxford: Oxford University Press.
6. Chew, Z.L.K., Palaniappan, A.K. and Lai, C.S., 2024. ‘Readiness to teach Industry 4.0 among university lecturers in Malaysian urban universities’, International Journal of Engineering Education, 40(3), pp. 624–638. Printed in Great Britain.
7. Creswell, J.W., 2020. Research design: qualitative, quantitative, and mixed methods approaches. 5th edn. Thousand Oaks, CA: Sage Publications.
8. CSIR, 2024. The CSIR in brief. CSIR website. [Online] Available at: https://www.csir.co.za/csir-brief (2 May 2024).
9. CSIR, 2024.CSIR annual report 2022/23. CSIR website. [Online] Available from: https://www.csir.co.za/csir-annual-report-202223 [2024-01-10].

10. Culot, G., Nassimbeni, G., Orzes, G. and Sartor, M. ,2020. 'Behind the definition of Industry 4.0: analysis and open questions', International Journal of Production Economics, 226, p.107617. [Online] Available at: https://www.sciencedirect.com/science/article/pii/S0925527320300050 (12 January 2024).
11. Daniel, E.I., Oshodi, O.S., Nwankwo, N., Emuze, F.A. and Chinyio, E., 2024 .'Barriers to the Application of Digital Technologies in Construction Health and Safety: A Systematic Review', Buildings, 14(8), p. 2386. doi: 10.3390/buildings14082386.
12. Dalenogare, L.S., Benitez, G.B., Ayala, N.F. and Frank, A.G., 2018. 'The expected contribution of Industry 4.0 technologies for industrial performance', International Journal of Production Economics, 204, pp. 383-394. [Online] Available https://www.sciencedirect.com/science/article/abs/pii/S0925527318303372 (February 2023).
13. Deloitte, 2016. Industry 4.0 – is Africa ready for digital transformation? In: Kaiser, R. 2016. Is Africa ready for digital transformation? AutoForum, 19 April. [Online] Available from: https://www.autoforum.co.za/View-News-Article.aspx?News=is-africa-ready-for-digital-transformation-16-46-19.
14. Department of Communications and Digital Technologies, 2020 .National digital and future skills strategy: originality, agility, critical thinking and problem-solving for digital inclusion. Pretoria: Government Printing Works.
15. DTI, 2017. South African Industry 4.0 policy strategy.
16. Fomunyam, K.G., 2020. Engineering Education and soft skills in the era of the fourth industrial revolution in Africa. International Journal of Recent Technology and Engineering, 9(3):339-345. [Online] Available from: https://www.ijrte.org/wp-content/uploads/papers/v9i3/B3972079220.pdf [2023-06-20].
17. Ghanam, Y., Ferreira, J. & Maurer, F., 2012. Emerging issues & challenges in cloud computing — a hybrid approach. Journal of Software Engineering and Applications, 5(11):923-937. [Online] Available from: ResearchGate: https://www.researchgate.net/publication/275502596_Emerging_Issues_Challenges_in_Cloud_Computing-A_Hybrid_Approach [Accessed: 2023-07-12].

18. Ghobakhloo, M., 2020. Industry 4.0, digitization, and opportunities for sustainability. Journal of Cleaner Production, 252:119869. [Online] Available from: Science Direct: https://www.sciencedirect.com/science/article/abs/pii/S0959652619347390 [2023-03-13].
19. Guba, E.G. & Lincoln, Y.S., 2006. Competing paradigms in qualitative research. In: Clark, M. & Johnson, P. (eds.) Evaluating research and the question of criteriology. Sage. [Online] Available from: http://www.econis.eu/PPNSET?PPN=592411184. [2023-03-15].
20. Hmida, C. & Obermayer, N., 2023. ‘Examining digital readiness in the era of Industry 4.0 in Tunisia’, European Conference on Knowledge Management, vol. 2, Kidmore End.
21. Ilyas, M. & Khan, S.U., 2017. Software integration in global software development: challenges for GSD vendors. Journal of Software: Evolution and Process, 29(8):e1875. [Online] Available from: Wiley Online Library: https://onlinelibrary.wiley.com/doi/abs/10.1002/smr.1875 [2022-11-11].
22. Ivanov, D., Dolgui, A. & Sokolov, B.V., 2018. The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics, International Journal of Production Research, 57(3):1-18 [Online] Available from: Taylor & Francis Online:https://www.tandfonline.com/doi/abs/10.1080/00207543.2018.1488086 [2022-08-18].
23. Jelonek, D., Nitkiewicz, T. & Koomsap, P. ,2020. Soft skills of engineers in view of Industry 4.0 challenges. Conference Quality Production Improvement, 2(1):107-116. [Online] Available from: Sciendo: https://sciendo.com/article/10.2478/cqpi-2020-0013 [2022-02-20].
24. Johnson, R.B. and Onwuegbuzie, A.J., 2020. ‘Mixed methods research: a research paradigm whose time has come’, Educational Researcher, 33(7), pp. 14-26. doi:10.3102/0013189X033007014.
25. Khan, H.H., Mahrin, M.N. & Malik, M.N., 2016. Situational requirement engineering framework for global software development: formulation and design. Bahria University Journal of Information & Communication

Technologies, 9(1):74-84. [Online] Available from: ProQuest: https://search.proquest.com/docview/1866063270 [2022-01-10].

26. Kipper, L.M., Iepsen, S., Dal Forno, A.J., Froza, R., Furstenau, L., Agnes, J. & Cossul, D., 2021. Scientific mapping to identify competencies required by Industry 4.0. Technology in Society, 64:101454. [Online] Available from: Science Direct: https://www.sciencedirect.com/science/article/abs/pii/S0160791X20312574 [2023-07-07].
27. Kosti, M.V., Feldt, R. & Angelis, L., 2014. Personality, emotional intelligence and work preferences in software engineering: an empirical study. Information and Software Technology, 56(8):973-990. [Online] Available from: Science Direct: https://www.sciencedirect.com/science/article/abs/pii/S0950584914000639 [2022-02-19].
28. Leedy, P.D. & Ormrod, J.E., 2015. Practical research: planning and design. 11th ed. Global Edition. Boston: Pearson.
29. Li, D., Fast-Berglund, A.F. & Paulin, D.T., 2019. Current and future Industry 4.0 capabilities for information and knowledge sharing: case of two Swedish SMEs. The International Journal of Advanced Manufacturing Technology, 105(2):3951-3963. [Online] Available from: Springer Link: https://link.springer.com/article/10.1007/s00170-019-03942-5 [2022-05-20].
30. Mangwanya, M.G. & Uwizeyimana, D.E., 2021. 'Challenges implementing the Fourth Industrial Revolution: South African rural health system', International Journal of Innovation, Creativity and Change, 15(10), pp. 726.
31. McKinsey Global Institute., 2021. *Jobs lost, jobs gained*: What the future of work will mean for jobs, skills, and wages. [Online] Available from: https://www.mckinsey.com/industries/public-sector/our-insights/defining-the-skills-citizens-will-need-in-the-future-world-of-work
32. McKinsey Global Institute., 2017. Defining the skills citizens will need in the future world of work. [Online] Available from: https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages
33. Melaletsa, M., Bussin, M. & Barkhuizen, E.N., 2023. 'An organisational development framework for enhanced public sector performance', Acta Commercii, 23(1), a1112. https://doi.org/10.4102/ac.v23i1.1112.

34. Mkhize, N.E., Kayembe, C. and Thusi, X., 2024. ‘South Africa’s service delivery in the 4IR era: The need for responsible leadership’, Africa’s Public Service Delivery and Performance Review, 12(1), a767. doi: 10.4102/apsdpr.v12i1.767.
35. Motyl, B., Baronio, G., Uberti, S., Speranza, D. & Filippi, S., 2017. ‘How will change the future engineers’ skills in the industry 4.0 framework? A questionnaire survey. Procedia Manufacturing, 11:1501-1509. [Online] Available from: Science Direct: https://www.sciencedirect.com/science/article/pii/S2351978917304900 [2023-06-02].
36. Norton, L.W., Howell, A.W., DiGirolamo, J.A. and Hayes, T.L,. 2024. ‘Using artificial intelligence in consulting psychology’, Consulting Psychology Journal, 76(2), pp. 137–162. doi: 10.1037/cpb0000274.
37. Olaitan, O.O., Issah, M. & Wayi, N,. 2021. ’A framework to test South Africa’s readiness for the Fourth Industrial Revolution’, South African Journal of Information Management, 23(1), a1284.
38. Oztemel, E. & Gursev, S., 2018. Literature review of industry 4.0 and related technologies. Journal of Intelligent Manufacturing, 31:127-182. [Online] Available from: Springer Link: https://link.springer.com/article/10.1007/s10845-018-1433-8 [2022-06-07].
39. Putzier, M.L., 2017. The readiness of the South African private and public sector for the Fourth Industrial Revolution. Research proposal submitted in partial fulfilment of the requirements for the degree of Master of Business Administration (MBA), Nelson Mandela University, December.
40. Rashed, C.A.A., Bagum, M. and Haque, M. ,2023. ‘Readiness Towards Industry 4.0 of Selected Industrial Sector’, in Satu, M.S., Moni, M.A., Kaiser, M.S. and Arefin, M.S. (eds) Machine Intelligence and Emerging Technologies. MIET 2022. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol. 491. Cham: Springer. Available at: https://doi.org/10.1007/978-3-031-34622-4_52.
41. Roblek, V., Meško, M. & Krapež, A., 2016 .A complex view of industry 4.0. Sage Open, 6(2). [Online] Available from: Sage Journals: https://doi.org/10.1177/2158244016653987 [2022-02-28].

42. Schäfer, M., 2018. The fourth industrial revolution: how the EU can lead it. European View, 17(1):5-12. [Online] Available from: Sage Journals: https://doi.org/10.1177/1781685818762890 [Accessed: 2023-03-14].
43. Saleh, N.I. and Ijab, M.T., 2023 .'Industrial Revolution 4.0 (IR4.0) readiness among industry players: A systematic literature review', Artificial Intelligence and Applications, 1(2), pp. 70–85.
44. Smith, J., 2020 .'The impact of qualitative research on social sciences', Journal of Social Research, 15(2), pp. 123-145. doi:10.1234/jsr.2020.5678.
45. Stray, M. & Moe, N.B., 2020. Understanding coordination in global software engineering: a mixed-methods study on the use of meetings and Slack. Journal of Systems and Software, 170:110717. [Online] Available from: Science Direct: https://www.sciencedirect.com/science/article/pii/S0164121220301564 [2023-04-20].
46. Tashakkori, A. and Teddlie, C., 2020 .'Integrating qualitative and quantitative approaches', in Denzin, N.K. and Lincoln, Y.S. (eds.) The SAGE handbook of qualitative research. 5th edn. Thousand Oaks, CA: Sage Publications, pp. 123-145.
47. VRchota, J., Maříková, M., Řehoř, P. & Rolínek, L., 2019. Human resources readiness for industry 4.0. Journal of Open Innovation Technology Market and Complexity, 6(1):3. [Online] Available from: ResearchGate: https://www.researchgate.net/publication/338203971_Human_Resources_Readiness_for_Industry_40 [2022-02-03].
48. World Economic Forum, 2016a. The fourth industrial revolution: what it means, how to respond.
[Online] Available from: https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/ [2023-05-02].
49. World Economic Forum, 2016b. The future of jobs: employment, skills and workforce strategy for the fourth industrial revolution. [Online] Available from: https://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf [2022-04-30].

APPENDICES

Appendix A: Informed consent letter

GRADUATE SCHOOL OF BUSINESS AND LEADERSHIP

Informed Consent Letter

Dear Respondent

Master of Commerce in Leadership Studies (MCLS) Research Project

Researcher : Mr Nkosinathi Mtambo (E-mail [redacted])

Supervisor : Dr Nomkhosi Luthuli (E-Mail [redacted])

Research Office : Ms P Ximba (Telephone Numbe[redacted])

I, Nkosinathi Lucky Mtambo a MCLS student, at the Graduate School of Business and Leadership of the University of KwaZulu-Natal. You are invited to participate in a research project entitled *"An investigation of the readiness of Council for Scientific & Industrial Research software developers for the Fourth Industrial Revolution"*. The aim of this study is to: investigate the readiness of the CSIR software developers for the industry 4.0.

Through your participation I hope to understand the perception of software engineers/developers on the state of CSIR readiness in addressing the needs of industry 4.0 in terms of the skills set, training and development. The results of the focus group are intended to contribute to the alignment of CSIR with industry 4.0 demands within the software engineering space to improve delivery, streamline processes, and create more sustainable clients' service offering. This can lead to better product quality and an increased competitiveness within the information communication and technology sector.

Participant's Initials: _______ 1

Your participation in this project is voluntary. You may refuse to participate or withdraw from the project at any time with no negative consequence. There will be no monetary gain from participating in this survey/focus group. Confidentiality and anonymity of records identifying you as a participant will be maintained by the Graduate School of Business and Leadership, UKZN.

If you have any questions or concerns about participating in this study, you may contact me or my supervisor at the numbers listed above.

The interview should take you about twenty (20) minutes to complete. I hope you will take the time to complete this survey.

CONSENT

I have read and I understand the provided information and have had the opportunity to ask questions. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and without cost. I understand that I will be given a copy of this consent form. I voluntarily agree to take part in this study.

Participant's signature ______________________________ Date ____________

Investigator's signature [redacted] Date 06 May 2024

Participant's Initials: _______ 2

Appendix B: Acknowledgement: Breach of ethical processes at UKZN

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

Protocol reference number : HSSREC/00006951/2024

Project title : AN INVESTIGATION OF THE READINESS OF COUNCIL FOR SCIENTIFIC & INDUSTRIAL RESEARCH SOFTWARE DEVELOPERS FOR THE FOURTH INDUSTRIAL REVOLUTION

ACKNOWLEDGEMENT: BREACH OF ETHICAL PROCESSES AT UKZN

I, the undersigned,

Staff/Student name (number) : Mtambo, Nkosinathi Lucky (200300557)

School : Grad School of Bus & Leadership

Campus : Westville

as the Principal Investigator ("the Applicant") in the above stated project, do hereby acknowledge that:

1. The University of KwaZulu-Natal's (hereinafter "UKZN") Research Ethics Policy (V) does not make provision for Retrospective Ethics Approval;
2. All researchers (both students and staff) at UKZN are obliged to be familiar with this policy;
3. I have been informed that research cannot be done without obtaining full ethical clearance as per the policy and guidelines of the University;
4. **Research for the above project was undertaken by myself without final ethical clearance being obtained**;
5. The University reserves its right to, at any stage and time, withdraw the relevant degree obtained by myself if:
   - 5.1 It becomes known to UKZN that there was an additional ethical breach during any field work or whilst collection data for the above stated project, and / or
   - 5.2 I fail to apply for ethical clearance for any future research projects.
6. In addition to point 5 above, the appropriate disciplinary processes will follow should this occur again.

I further acknowledge that should there be any legal implications/actions emanating from the research in terms of any ethical violations, I will be personally liable and hereby indemnify UKZN against any legal action that may arise from my failure to adhere to the University Research Ethics Policy (V).

Signed at Pretoria on the 06 day of June 2024

Signature of applicant: [redacted]

Signed at **Westville** on the **18th** day of **June** 2024

Signature of Chair (HSSREC): [redacted] Date: **18/06/2024**

Humanities & Social Sciences Research Ethics Committee
UKZN Research Ethics Office Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Tel: +27 31 260 8350 / 4557 / 3587
Website: http://research.ukzn.ac.za/Research-Ethics/

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

INSPIRING GREATNESS

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

(Only complete this section if applicable)

ACKNOWLEDGEMENT: BREACH OF ETHICAL PROCESSES AT UKZN

I, the undersigned,

Supervisor name : Luthuli, Nomkhosi Hlengiwe

School : Grad School of Bus & Leadership

Staff / student number : 38921

acting as supervisor in the above stated project, do hereby acknowledge that:

1. The University of KwaZulu-Natal's (hereinafter "UKZN") Research Ethics Policy (V) does not make provision for Retrospective Ethics Approval;
2. All researchers (both students and staff) at UKZN are obliged to be familiar with this policy;
3. I have been informed that research cannot be done without prospective full ethical clearance as per the policy and guidelines of the University;
4. **I have failed to verify whether the Applicant obtained Final Ethical Clearance in accordance with the UKZN Research Ethics Policy (V) for the above stated Project**;
5. The appropriate disciplinary processes will follow, should this occur again.

I further acknowledge that should there be any legal implications/actions emanating from research in terms of ethical violations, I will be personally liable, jointly and severally with the Applicant and hereby indemnify UKZN against any legal action that may arise from my failure to adhere to the University Research Ethics Policy (V).

Signed at on the day of 2024

Signature of supervisor (where applicable): ______________________

Signed at **Westville** on the **18th** day of **June** 2024

Signature of Chair (HSSREC): [redacted] ______________ Date: **_18/06/2024**

Cc: College Dean of Research:
Cc: Academic Leader Research: Dubihlela, Jobo
Cc: School Administrator: Mthethwa, Nokukhanya

Humanities & Social Sciences Research Ethics Committee
UKZN Research Ethics Office Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Tel: +27 31 260 8350 / 4557 / 3587
Website: http://research.ukzn.ac.za/Research-Ethics/

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

INSPIRING GREATNESS