UNIVERSITY OF KWAZULU-NATAL

Exploring the Skills Challenges of Robotics at Anglo American Platinum

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Abstract

The research focuses on investigating the skill challenges related to a people centric approach to adoption of advanced technologies in the mining industry, particularly a people centric robotics technology adoption. Given the reality that the South Africa idealises a people-centric approach to robotics technology adoption, the research investigates how Critical Systems Thinking (CST) can facilitate this people-centric adoption of robotics technology, ensuring alignment with responsible mining practices. The study aims to explore how the required skill sets for robotics adoption can be developed through an early talent development strategy using the Anglo-American Platinum Schools Project as a case study. The research provides important insights to influence policymaking that can ensure the successful adoption of robotics technologies in the mining industry. It primarily contributes insights into the theories concerned with the use of critical systems thinking in the adoption of emerging technologies. The research contribute to the need for expanding literature on how the mining industry can adopt robotics technologies in a relevant and responsible manner.

Key words: Anglo American Platinum Schools project, Automation and robotisation in mining, Systems Thinking ,Critical systems thinking technology, Integrated early talent strategy, People centric technology adoption, Technology adoption skills.

Declaration

I, Jill Carol Sesoko, declare that:

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

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Signed:

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My mother Sarah Diile Sesoko,
My great aunt Matsie Poppy Sesoko,
To my children, Boikanyo Matshana and Molebatsi Matshana,
My brother Leon Serialong Sesoko,
My God given sisters Bongi Mnguni and Sisi Modise

In appreciation of the life lived by my Grandfather Edward “Aku” Tlabeane , I will forever remain thankful

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List of Acronyms

4IR	: 4^{th} Industrial Revolution
AI	: Artificial Intelligence
CST	: Critical Systems Thinking
CSH	: Critical Systems Heuristics
DBE	: Department of Basic Education
DHET	: Department of Higher Education and Training
ESG	: Environmental, Social and Governance
HCD	: Human-Centred Design
ICT	: Information and Communication Technology
IMS	: Information Management Systems
IT	: Information Technology
LHD	: Load-Haul-Dump
LMS	: Learning Management System
MCSA	: Mineral Council of South Africa
NDP	: National Development Agenda
SSM	: Soft Systems Methodology
SD	: Systems Dynamics

CHAPTER 1 – INTRODUCTION

1.1 INTRODUCTION

Advanced technology developments are rapidly replacing human workers with automation, artificial intelligence (AI), and robotics technology (Fathiyah, Kamaruzaman, Azrul & Mohamad, 2019). This shift is reshaping the economy, society, health, education, employment, and skill development (Kloosterman, Koper, Geradts, Mapes, Van Asten, Van den Berg, Van der Steen & Verheij, 2015). Given the rate at which rapid advancement of technology is happening, it is estimated that workforce skills will change within the next 15 years due to ongoing technological innovation and the sharing of workplaces with AI platforms. (Brynjolf & Mitchell, 2017; Malik, Tripathi & Gupta, 2021).

The mining sector has not been immune to this infiltration of technological innovations (Barnewold & Lottermoser, 2020; Kalenov & Kukushkin, 2021). The industry is already embracing Industry 4.0 technologies and increasingly making use of innovative and cutting-edge technologies to run more efficient operations, manage risk, improve health and safety, reduce the cost of maintenance and extraction, and bring about a skills uplift (Mineral Council of South Africa, 2015).

In addition, the COVID-19 pandemic further accelerated digitalisation, automation, and robotics adoption in mining (Atif, Cawood & Mahboob, 2020). Most importantly, the industry recognises the necessity of a people-centric approach to the digital transformation of the mining sector. This concept of a people-centric technology adoption of technology by the mining sector is being advocated by the Minerals Council of South Africa as an approach that will address the threat of high levels of unemployment, poverty and inequality that a pure technology-focused technology adoption will bring. According to the Mineral Council of South Africa (2015), a pure technology-focused digital transformation of the industry will not be socially acceptable. (Mineral Council of South Africa, 2015)

The Mineral Council of South Africa encourages a digital transformation of the industry that is not only focused on technological issues but also issues related to culture and the upskilling and reskilling of the workforce (Nabi & Nabi, 2019). The mining industry needs to embrace 4.0 technologies in a relevant and responsible manner (Parades & Fleming-Munoz, 2021). Even though the realities of the pressures faced by the South African mining companies to compete on cost, environmental, social and governance issues on a global scale cannot be overlooked, the need for digital transformation in the mining sector should be done in a balanced way without negatively affecting the transformation of mining companies, institutions, communities, and societies affected by the mining industry (Acemoglu & Restrepo, 2018).

1.2 THE ANGLO AMERICAN PLATINUM'S INTEGRATED EARLY TALENT DEVELOPMENT STRATEGY TO ADDRESS A PEOPLE-CENTRIC DIGITAL TRANSFORMATION AGENDA

As part of addressing the skill challenges of a future mechanised, modernised, and digitalised mining in a manner that aligns with shared value as created through social compacting with local host communities, (Chipangamate, Nwaila, Bourdeau & Zhang, 2023). Anglo American Platinum (AAP) established the Anglo American Platinum School Project (AAPSP). The project is a key component of an integrated early talent development strategy for delivering a sustainable and high-performing early talent pool that is future-proofed for the fourth industrial revolution (4IR) (Mpofu & Nemashwake, 2023;de Holando, 2024). It is intended to provide a platform for meaningfully co-creating early talent development paths required by future automation, AI and robotics-driven mining operations (Attah & Amoah, 2023).

It is envisaged that the project will institutionalise processes and structures within AAP Human Resource Development that will result in the successful localisation of early talent human capital from host communities. It is aimed to address the foundation of early talent capital that can drive the culture, technologies, business models, and strategies required by today's and tomorrow's AAP mining ecosystem. The central premise of the AAPSP is anchored on the understanding that today's and tomorrow's AAP's sustainable competitive advantage cannot happen without taking along the skills, experience, creativity, imagination, and brain power of technically oriented youth from the host communities. The AAPSP is therefore positioned as a platform to identify, fast-track development and pipelining of early talent that can solve for a people centric adoption of 4.0 technologies.

To deliver on this envisaged value proposition, the AAPSP is thus packaged to deliver a set of four deliverables, each linked to clear targets that can be regularly monitored, reviewed, and adjusted to address the dynamics of both the ever-changing external and internal early talent environment.

These dimensions can be summarised as follows:

1. Development and incubation of technical skills required by future mechanised, digital, and modernised mining.
2. Innovation in localising technical education excellence for the host community.
3. Partnerships and collaboration with technology 4.0 industry and education experts in curriculum development of 4.0 technologies and technical skills.
4. Co-creating meaningful learning paths to develop and harvest required skills from high school years.
    a. Mining infusion programme
    b. Opportunities for learners to identify and solve mining-related solutions (Exposure to real complex mining problems)
    c. Identification of thematic areas driving responsible mining
    d. Coding
    e. Robotics

However, the main problem remains the extent to which the development of the envisaged future robotics skills can be argued to be able to solve for people-centricity in technology adoption. Producing skills that can use robotics is happening in complex social dynamics where the advancement of the socio-economic conditions of the host community is critical. Building skills that only solve the capability to address the variation of the use of robotics technology and ignoring the skills that can be able to address the conflicting value-laden societal dynamics and other factors that hinder sustainable utilisation of robotics technologies is a problem for people-centric robotics adoption. It is important for AAPSP's early talent strategy to focus on the lack of skills that can enhance the relevant and sustainable utilisation of robotics technology.

The fundamental proposition of this study is that a management science-based problem-solving framework is an important component that can position the Anglo American Schools Project to develop an early talent pipeline of the future in a manner that is cognisant of creating value by solving for a people-oriented robotics adoption strategy (Jokonya, 2016; Khubana, 2022; Bailey & Bailey, 2019).

1.3 SYSTEMS SCIENCE AND ADOPTION OF ROBOTICS TECHNOLOGY

The use of systems science to provide problem-solving techniques that avoid isolationism and reductionism in the adoption of robotics is the central argument of this research. It emanates primarily from the premise that the problem with adopting 4.0 technologies is not so much about how to use the technologies but what hinders the utilisation of the technology (Linde, 1991). Innovation in the adoption of technology is about the development of new solutions that address unmet needs, which create a lasting impact (Ralston, Hargrave & Dunn, 2017).

Critical systems thinking provides a framework to address the adoption of robotics technology in a responsible and relevant manner to achieve usability and applicability (Ralston, 2017). As explained in section 1.1, automation and robotics are altering traditional ways of thinking and challenging the norms and standards used to provide social and economic benefits to impacted stakeholders. The study espouses that critical systems thinking will be able to provide a framework for guiding an integrated early talent development strategy for the Anglo American School Projects that ultimately allows for the adoption of robotics to be done in a holistic manner, avoiding isolationism and reductionism and thereby addressing value add in the new way of social and economic beneficiation as bought about by automation and robotics.

This is because the critical system thinking framework provides a lens through which the early talent development strategy for the adoption of robotics technology can be aligned to responsible mining and address the skill challenges that are required in this regard. Critical systems thinking framework can be used to provide a foundation for designing and implementing skill sets that are critical for ensuring that adoption of robotics technology achieves responsible mining (Khubana, 2022; McKinsey, 2019; Ralston, 2017). The study, therefore, aims to explore and highlight the skills required to be infused as part of early talent development by the AAPS to solve for the ability and capability to socially compact the creation of a shared value in the context of a robotics-driven digital transformation future.

The importance of this capability is critical, considering that the use of robotics in AAP happens and will continue to exist in the context of ethical and legal issues, regulatory challenges, and policy requirements. Robotics and automation will affect drilling, blasting, train, and truck driving, amongst other functions which are mostly drawn from local host communities. It is therefore important that the AAPS project takes these considerations very seriously in crafting robotics adoption strategies and skills that are capable of not only being able to use robotics technologies but skilled in solving the ethical, social, and human rights legal likely to result from deploying robotics technology. (Rogers et al., 2019)

1.4 PROBLEM STATEMENT

The adoption of emerging technologies in developing economies is hindered by a complex combination of factors, including the lack of fit between the technologies and the developmental goals of developing nations and the lack of skills to adopt and use the technologies. The failure in the successful implementation of revolution 4.0 technologies in the context of developing economies is a symptom of an underlying hindrance in the use of technologies to benefit the achievement of economic and social transformation goals and targets. Academic concern as far as the adoption of technologies in developing economies is concerned is no longer about how to speed up technological advancement but about what hampers the utilisation of technologies in developing countries" (Lind, 1991; Toyama, 2018).

The adoption of emerging technologies in developing economies can be challenging due to the misalignment of technologies with development goals and the lack of technical skills required to use the technologies. In addition, the challenge with the existing skills is that they are not equipped to address this misalignment between technologies and development goals of these economies. (Anadon, Chan, Harley, Matus, Moon, Murthy & Clarke, 2015; Guo, Huang, Liu & Xiang, 2018)

Even though the mining industry in developing economies is traditionally seen as a non-innovative field, it is nonetheless slowly changing by embracing robotics and innovative techniques due to the observed benefits of these technologies. The increase in robotics applications, however, is coupled with issues, challenges and requirements that affect the integration of robotics with sustainable innovation in the mining sector (Lopez, 2018). If not carefully considered, the adoption of robotics technology in the mining industry can have negative consequences due to failure to solve the social, political, and economic realities that mining operations in developing economies are faced with. (Lind, 1991)

By taking the time to understand the local context and the potential impacts of the technology, mining companies in third world economies can ensure that they are adopting robotics in a responsible way. The mining houses in this context will need to consider approaches that can help them achieve successful technology adoption strategies that are aligned to their socially compacted shared value, considering their social licence to operate (Rogers, Kahraman, Drews, Powell, Haight, Wang, Baxla & Sobalkar, 2019).

1.5 SIGNIFICANCE OF THE RESEARCH

Previous research on skill challenges in technology adoption has primarily emphasised the role of quality education and technology's potential in addressing skills challenges. This study takes a distinct perspective, highlighting the complexities inherent in developing countries that hinder the sustainable adoption of 4.0 technologies. The lack of skills is not solely due to educational challenges but involves navigating the contexts of technology adoption in developing nations.

The skills challenge impeding inclusive economic transformation in developing economies cannot be solely attributed to problems with the quality of education (Dlamini, 2019; Henderson, 2011; Takariwa, 2019). Moreover, the belief that technology is the sole solution has its limitations (Lind, 1991; Minerals Council of South Africa, 2015).

Not only are the emerging technologies not fit to solve developmental goals, but the skills applied to adopt the technologies are also not fit to solve for making the technology relevant. It proposes a critical systems thinking (CST) based problem-solving approach as a systems-based management science in adopting emerging technologies and exploring the skills challenges that can solve for relevancy in the context of third world mining operations. This argument aligns with the challenge of adopting 4.0 technology in third world economies, where relevance and purpose are vital for responsible, sustainable solutions (Lind, 1991; Bailey & Bailey, 2019).

1.6 WHY IS THIS STUDY WORTH INVESTIGATING?

This paper aims to influence policymaking of successful robotics technology adoption processes and procedures for the mining sector. It offers innovative insights into emerging technology adoption and skill challenges. The majority of the previous research on skill challenges addressed other issues such as education quality and problems and reluctance in education policy implementation, and the role of technology in addressing skill challenges.

This study will contribute to mining companies' technology adoption frameworks and policies, aiding mining management and executives in crafting effective technology plans. It explores the correlation between technology utilisation and required skills in the mining sector of developing nations. It pioneers the application of CST as a framework for responsible technology use. The results of the study can be used to guide technology adoption, staff induction, and policy development. The study is also beneficial for leadership development students focusing on systems thinking. Moreover, it informs a people-centred technology adoption.

1.7 SIGNIFICANCE OF THE STUDY

The mining industry is experiencing a transition towards being more automated and system- and machinery-driven in order to achieve efficiency, safety and environmental goals (Lawrence Lien, Mining Engineering, 2011). This transition is evident in AAP, and it is expected that this transition will accelerate as new technology becomes proven to be affordable.

The adoption of robotics by AAP mines requires that this technology be adopted in the most relevant and responsible manner that would not have negative consequences of widespread unemployment and negative economic impact on local communities (Minerals Council, 2015).

In addition, as wil be later seen in the literature review, the challenge of skills is not only a result of a challenged education ecosystem and the challenge of replacing scarce quality skills with technology but also a challenge of addressing the hindrances of utilisation technology. The main contributors to the hindrance of utilising technology being irrelevancy and lack of fit, causing irresponsible and negative effects to the transformation goals in the mining sector (Lind, 1991).

This, therefore, means that in adopting robotics technology, AAP must be concerned with skills that have the capability to solve for relevancy and responsible implementation of robotics technology. It also means that robotics technology implementation should not only be about achieving the goals and vision of the design of various applications of robotics technology, but it should solve other critical end goals of positive contributions to institutional and societal changes affected by AAP mining operations.

A concern with adopting robotics in a manner that is sustainable by positively contributing to transformation goals (sustainability, socio-economic development, diversity, inclusion) should be based on a strategy that makes it possible to not only unpack and understand the usage, variation of usage and design of robotics but to bring forth non- transparent but real ideologies and powers driving designed use of the robotics technology application, questioning and where applicable redressing the social, ethical, legal, governance and sustainable consequences of the use of robotics technology.

It means that the future talent pipelining and the current reskilling programme should support the adoption of robotics technology that is based on a full analysis, understanding and implications of the power, ideologies, design, variation of use, organisational changes and societal changes that make up automation and robotics.

1.8 AIMS OF THE RESEARCH

The main aim of the study is to explore the skills challenges of robotics at the AAP. This study aims to explore the application of Critical Systems Thinking (CST) as a problem-solving framework to address the skill challenges of adopting robotics technology at an early stage of talent development using the AAP School Project as a case. The goal is to explore how relevancy, fit for purpose, conflicting values, system skill development, and positive transformation can be addressed when adopting robotics technology. CST is viewed as not only essential for enhancing a people-centred robotics adoption but also a framework that can guide skill evolution in emerging technology adoption.

The study delves into the skill challenge discourse by investigating how CST serves as a management science approach to address skills challenges tied to technology adoption. It not only identifies skill gaps in mining but also enhances responsible technology use. The research examines how implementing CST offers mining companies a framework to adopt robotics while optimising skill development and transformation goals.

The research does not analyse transformation outcomes due to critical systems thinking use but highlights how the absence of a CST approach hampers relevance, applicability, and responsible adoption, affecting inclusive transformation negatively. The focus of the study is not on 4IR or explaining its importance but on showcasing how a system thinking approach aids in addressing skill challenges and achieving transformation goals in technology adoption.

The case study approach will be used to contribute knowledge on applying CST in early talent strategies to the adoption of robotics adoption within the mining sector. The intent is to enable mining to effectively use this approach to tackle skill challenges and meet transformation goals at an early stage of creating and developing an early talent pool.

In addition, it will also contribute new insights into the adoption of emerging technology theories, skill challenges and body of knowledge, given that there is not enough literature on how the mining industry can adopt robotics technologies in a relevant and responsible manner. Past academic research on skill challenges has focused on the following:

- Skill challenges brought about by problems with the education system. Low quality of education.
- Unwillingness of those responsible for education to implement reformed education policies.
- Technologies being the answer to delivering productivity, quality, safety and reduced costs because current skills are not able to deliver.

The research will add to the conversation of frameworks in the adoption of technology in the mining sector; it will also help many executives to create a proper technology adoption plan and will add to the conversation about steps to be taken with respect to emerging technologies adoption. It will also bring new insight by exploring the relationship between the utilisation of technologies and skills that are necessary to increase the relevancy of technology to the mining sector in the developing world context. It is breaking new ground in terms of the application of CST skills as a framework for designing and planning for relevant and responsible use of technology.

The results of the study may be used when companies are adopting new technologies, induction of new staff and developing policies. The results will be used by other fellow students in leadership development who are specifically focusing on systems thinking theory and practice. It can also be used in situations of adopting technologies in a relevant and responsible manner.

1.9 AIM OF THE STUDY

To explore the skill challenges of robotics at AAP.

The research objective:

1. To investigate the benefits of using CST in addressing skills challenges of adopting robotics technology at AAPSP.
2. To determine the skills challenges of using the CST approach relating to robotics technology.
3. To give recommendations on how AAPSP can use a CST approach to address issues hindering.

1.9.1 Research Question

1.9.1.1 Research Questions:

1. What are the benefits of using CST in addressing skills challenges for adopting robotics technology at AAPSP?
2. What are the skills challenges identified in using the CST approach of robotics technology?
3. What could be done to address skills challenges using the CST approach of robotics?

1.10 RESEARCH APPROACH

In describing the methodological underpinning of this study, the writer followed the framework of the research onion. The research onion was created by Saunders, Lewis and Thornhill (2019).

The chosen philosophical stance for this study is interpretivism. This research paradigm emphasises understanding individuals' beliefs, motivations and thought processes to interpret collected information about a subject. The study employed the qualitative method due to its aptness for comprehending underlying reasons and people's opinions on specific issues or problems.

Unlike quantitative approaches, the qualitative method does not depend on numerical data. The collected data was non-numerical, offering valuable insights into the research problem and effectively achieving the study's objectives. The methods utilised qualitative interviews. A total of 12 participants were interviewed using an open-ended qualitative interview tool to understand, assess and recommend how managers and educational systems can benefit the robotics technology early talent skills development of AAP.

1.10.1 Limitations

1.10.1.1 Lack of Previous Research Studies on the Topic

The focus of emerging technologies is a new field and, therefore, has limitations in existing academic research theories to draw from. This poses a challenge because research typically relies on previous studies for theoretical support guiding research questions. However, the scarcity of relevant literature restricts the researcher's ability to draw comparisons and extrapolate ideas. In the absence of previous research, the study ventured into uncharted territory, establishing a unique research typology. Despite limitations hindering comprehensive answers, they exposed gaps in the literature, underscoring the need for future research in this field.

1.10.1.2 Time Constraints

Similar to deadlines in various domains, academic researchers face time constraints to submit completed reports within study timelines. These practical limitations restrict the time for examining research problems and observing temporal changes. Acknowledging these constraints, the researcher highlights the necessity for future studies to address the research problem and other potential inquiries that this study may not have uncovered.

1.10.1.3 the Difficulty of Investigating Causality

Qualitative research requires careful planning to ensure that the results obtained are accurate. There is no way to analyse qualitative data mathematically or statistically. This type of research is based on opinion and judgement rather than results. Because all qualitative studies are unique, it is difficult to replicate them.

1.10.1.4 Delimitations

This study focuses solely on issues tied to the adoption and responsible implementation of specific systems within the AAPSP. It does not address similar concerns within other companies or problems arising from the adoption of different systems within Anglo Platinum. The study's scope is limited to AAPSP staff members. Exclusions include:

- Contractors, remote site employees, and vendors of AAP School Project.
- Union representatives and past employees of the company.

1.11 RESEARCH METHODOLOGY

The techniques and procedures for this study were guided by the Research Onion framework.

Data Collection:

- Semi-structured interviews were conducted, with open-ended questions to get respondents' opinions in their own words.
- Other methods included collecting texts and documents, observational notes, , open-ended questions, interview transcripts, and telephone interviews.
- The researcher used Qualitative Research Methods to understand respondents' experiences and decision-making processes. This approach allowed themes and findings to emerge through careful analysis, providing valuable insights into the complex issue at hand.

Data Analysis:

- Content Analysis was used to identify patterns that emerge from text, by grouping content into words, concepts, and themes.
- Narrative Analysis was used to understand the stories people tell and the language they use to understand these stories.
- The analysis of qualitative data often began as soon as the data were available and accessible. The researcher aimed to understand what the collected data represents by gathering, structuring, and interpreting each datum received.

The study has several limitations:

- Lack of previous research studies on the topic: The study focuses on emerging and relatively new technologies, and therefore, previous research studies that could be cited and referenced are scarce. This limits the extent to which comparisons and interpolations can be made. However, this also provides an opportunity to identify gaps in the literature and indicates the need for further research.
- Time constraints: Like all projects, this study was subject to deadlines, limiting the time available to study the research problem and measure changes over time.

The researcher acknowledges the need for future studies to answer this research problem and other questions that may have been uncovered by this research.

- Difficulty of investigating causality: Qualitative research requires careful planning to ensure accurate results. Since it’s based on opinion and judgment rather than results, and all qualitative studies are unique, it’s difficult to mathematically or statistically analyze qualitative data and replicate the studies.

Delimitations:

The study also had several delimitations

- The study does not cover problems and issues associated with the adoption or responsible implementations of other systems within the Anglo Platinum company, nor does it look at similar issues in other companies.
- The study is limited to the members of the Anglo Platinum staff within the geographical area of the Gauteng province and to AAP partner institutes of higher learning which AAP has a MOU with .

1.12 OVERVIEW OF THE RESEARCH DISSERTATION

Chapter 2 addresses the three research questions and research objectives outlined in section 1.7. The chapter reviews technology adoption theories and assesses their relevance to robotics technology adoption. The chapter will reflect on how scholarly articles explain the benefits of using CST when adopting robotics technology. It will also explore the theoretical understanding of the skill challenges of using CST in adopting robotics technology.

Chapter 3 focuses on the research design considerations based on the theoretical foundation of robotics technology adoption. It starts with a situational analysis of the problem, outlining challenges tied to robotics technology adoption. The chapter elaborates on the research approach, procedures, and methodologies, enabling readers to assess the study’s reliability and validity. It encompasses the research type, data selection and collection methods, analysis process, tools, materials, and the researcher’s rationale for method choices.

Chapter 4 centres on the case study, detailing the inquiry's conduct, methods, responses, and data interpretation. The chapter covers data collection from organisational documents, archival records, interviews, direct observations, participant observations, and physical artefacts.

Chapter 5 concludes the research, deriving conclusions from the literature and case study outcomes. It will spotlight unaddressed matters and provide recommendations for future research in the field.

1.13 CONCLUSION

The introduction chapter set the tone for the need to research the impact of emerging technology advancements on the future strategic workforce, particularly in the South African mining industry. Automation, artificial intelligence, and robotics are replacing human workers, causing shifts in various sectors. More than one-third of essential workforce skills are projected to change within 15 years, emphasising the importance of adapting to the 4IR era.

The mining industry is embracing Industry 4.0 technologies, aiming for efficiency, risk management, and skills enhancement. However, challenges arise in adopting these technologies while maintaining positive transformation. The need for a people-centric approach is vital, considering complexities in adopting technologies in a responsible manner because of solving for relevancy, applicability and accountability, leading to a positive contribution to shared value, environmental, social and governance (ESG) and positive transformation of the mining sector.

This research intends to explore how CST can facilitate relevant and accountable adoption of robotics technology, with a focus on early talent development. The research question centres on how CST can enhance the applicability of robotics technology in the mining sector while addressing skills challenges. The philosophical stance is interpretivism, and the approach is qualitative, emphasising understanding through non-numerical data.

Chapter 1 provided an overview of the research, highlighting the context, challenges, and significance of exploring technology adoption in the mining sector. It also introduced the primary research questions and methodology, setting the stage for the subsequent chapters.

CHAPTER 2 – LITERATURE REVIEW

2.1 INTRODUCTION

The previous chapter introduced the research study and centralised the rationale for investigating skill challenges related to the adoption of robotics technology. The focus of chapter one was to position the importance of being concerned about the resultant challenges of not adopting robotics technology in a responsible manner, especially in the mining sector. It also outlined the scope of the research study and the proposed methodologies to be used in conducting the research.

This chapter focuses on technology adoption theories. It will first review various theoretical arguments that have contributed to the knowledge of how best to adopt emerging technologies. The unitary approach to studying technology will be reviewed in the context of its proposition for the adoption of robotics technology. Thirdly, the chapter will review contributions made by the field of ergonomics theory of designing and adopting technology in the mining sector. Fourthly, this chapter looks at contributions made by development theories' plight of relevant and responsible adoption of technologies for developing economies.

In the final analysis, critical systems thinking will be reviewed from the perspective it provides as a system and management science problem-solving technique that has been used in the academic literature for the adoption of technology. In accordance with Shi (Shi, 2006), a literature review involves determining what has already been done and said about the topic. Ridley opines that literature reviews should show what has been achieved by previous researchers. It must also provide an overview of the current situation and current arguments, opinions and what other researchers feel has not been adequately addressed (Ridley, 2012). The literature review chapter seeks to position a reference point that centralises various theories and thinking about robotics technology adoption.

As stipulated by Ridley's explanation of the purpose of literature review as being a part of the thesis where reconnections are made between the source of the text and where one position a driving force and jumping off point (Ridley, 2012), the chapter will in the final analysis anchor critical system thinking as a theoretical basis for achieving a people-centric robotics technology adoption based on the understanding of academic writings on its benefits and limitations in guiding technology adoption. In an attempt to find a direct response to the research objectives and questions of the study, this chapter will also seek to understand what the literature is saying about the skills challenges of using critical systems thinking approaches in adopting robotics technology.

2.2 ADOPTION OF ROBOTICS TECHNOLOGY IN MINING

Mining evolved through technological stages from steam and mass production to currently being robotics, electronics, and technology-driven (Lopes et al., 2018). Robotics technology has gradually permeated the mining industry with applications in material transport, digging, and loading, enhancing productivity, safety, and efficiency.

Compared to past revolutions, the digital mining era is more complex because it demands an integration of diverse technologies. This has put pressure on mining companies to redefine their technology management strategy in an obligation to retrofit smart processes into their entire value chain systems (Zulu et al., 2021). Digitalisation has put mining companies on the front line of confrontation with rapidly changing business environments. Their business models are required to adapt to change while expected to sustainably create value.

Companies navigating digitalisation must sustainably create value, aligning with external factors and stakeholders (Tomita, 2022). It is for this reason that reporting standards such as the integrated reporting standard now emphasise value creation through relationships and resources as a determining factor for compliance in the context of the digital era (Tomita, 2022). Automation and artificial intelligence (AI) promise transformation but also pose job displacement risks (Kalenov and Kukushkan, 2021; Barnewold and Lottermoser, 2020). COVID-19 accelerated digital adoption in mining, prompting concerns about its impact on the workforce, education, and society (Green & Vogt, 2009; Neale & Africa, 2012; Price Water Coopers, 2019).

2.2.1 Automation and robotics technology setting an exponential growth of zero entry mining and green industrialisation

In the not-so-distant future, a robotic renaissance is poised to reshape the mining sector's workforce, (Pouresmaieli, Ataei & Taran, 2023; de Holanda, 2024; Zhironkina & Zhironkin, 2023). The ILO forecasting a shift as 137 million roles transition from human hands to automated counterparts (Knights & Yeates , 2021) . Deloitte echoes this sentiment, envisioning a landscape where one-third of jobs dissolve into the digital ether, thanks to technological marvels (Buchholz & Briggs, 2020.).

The mining industry stands on the cusp of an automation revolution, driven not by green ambitions but by the relentless pursuit of productivity, health, and safety. This mechanized metamorphosis promises round-the-clock operations, maximizing input utility, sometimes enhancing the old rather than ushering in the new. Mining's metamorphosis is underpinned by a symphony of sensors, amassing data mountains and catapulting the industry into the smart extraction and processing era, synonymous with Industry 4.0. AI's ascendancy rides on the back of ever-evolving algorithms, hardware, and sensor suites, eagerly embraced for their transformative potential.

Robotics' rise charts an exponential trajectory, with the research heralding a doubling of robot density in a mere five years (Knights & Yeates , 2021). This fusion of AI, machine learning, computer vision, and natural language processing births a new paradigm of green industrialization in the mining sector (Pouresmaieli, Ataei & Taran, 2023; de Holanda, 2024; Zhironkina & Zhironkin, 2023).

Globally, mining's frontier pushes towards zero-entry operations, where human presence fades into obsolescence, unlocking the riches of complex ore bodies once deemed untouchable. Currently ,australia leads this charge, reaping productivity and safety rewards as it pioneers autonomous solutions across the mining value chain. (Knights & Yeates , 2021).

Zero-entry mining beckons a radical redesign of the mining landscape, unlocking the full potential of ore bodies that lie beyond reach, deep and fraught with peril. The Internation Conference on Industrial Technology (ICIT) presented a compelling case for zero-entry mining, highlighting its potential to revolutionize safety and economic value in the industry. (Knights & Yeates , 2021).

The key benefits identified for zero entry mining include:

- Enhanced safety: By removing humans from hazardous mining zones, the risks associated with man-machine interactions, vehicle collisions, rock falls, and exposure to harmful substances are significantly reduced.
- Economic advantages: Zero-entry mining promises increased revenue, lower operating costs, reduced capital expenditure, and an extended lifespan for mines.
- The transition to zero-entry mining involves two major shifts in value:
- Complete removal of personnel from mining zones, with a commitment to maintain these areas as human-free.
- Redesign of mining equipment for autonomy, which further mitigates safety risks.

2.2.2 Challenges of a AI driven automation and robotics mining

It is however noting that the rise of AI-driven automation and robotics in mining is not as clean as the promise it heralds, and this is not only due to the side effects it will have on social license to operate (de Holando, 2024) but also due to the human rights concerns that seems to be at risk.as a result of artificial intelligence.(which is unfortunately the engine of behind robotics technology)

AI has been criticised for compromising human rights (Crabbe, Leader, Hall & Burdett 2023; de Holando, 2024; Stemmler, 2023) for the following reasons :

- Discriminatory algorithms: AI systems may inadvertently perpetuate biases.
- Work transformation: Changes in the nature of work could affect societal status and employment opportunities.
- Vulnerable groups: Certain populations may face increased risks.
- Decision-making: AI’s role in employment decisions could lead to ethical dilemmas.

Academic literature in this case suggest that the solution to ethical and human rights debate around AI will be brought about by reframing adoption of AI driven technology to emphasize the systemic nature of AI ecosystems, addressing issues like data protection, security, biases, economic inequality, and the influence on democratic processes. The response involves a multi-faceted approach, including technical solutions, professional guidance, standardization, and regulatory mechanisms to mitigate these risks and ensure ethical AI deployment (Crabbe, Leader, Hall & Burdett 2023; de Holando, 2024; Stemmler, 2023

2.3 INFORMATION MANAGEMENT SCIENCE-BASED TECHNOLOGY ADOPTION THEORIES

The process of technology adoption is intricate and socially influenced, encompassing various considerations that shape both individuals' and organisation's decisions. Individuals construct unique yet malleable perceptions of technology that influence their adoption decisions. Successfully facilitating technology adoption must address cognitive, emotional, and contextual concerns. (Straub, 2009). How and why individuals and organisations adopt technological innovations has motivated a great deal of research. (Straub, 2009; Meuter, Ostrom, Roundtree, & Bitner, 2000; Dapp, Stobbe & Wruck, 2012; Lai & Zainal, 2014; Lai, 2016).

Several prominent theories emanating from the discipline of information systems have been developed to comprehend technology adoption, each offering unique insights into the technology adoption process:

1. Diffusion of Innovation (DI) (Roger, 1983): This theory explains how innovations spread through social systems and highlights factors influencing their adoption.
2. Theory of Reasoned Action (TRA) (Ajzen, 1991; Fishbein, 1975; Ong, 2008): TRA emphasises individual attitudes and subjective norms in shaping adoption decisions.
3. Theory of Planned Behaviour (TPB) (Ajzen, 1991): Building on TRA, TPB includes perceived behavioural control to predict intentions and subsequent actions.

4. Decomposed Theory of Planned Behaviour (Taylor & Todd, 1995): An extension of TPB, this model dissects perceived behavioural control into facilitating conditions and self-efficacy.
5. Technology Adoption Model (TAM) (Davis, 1989; Roger, 1989): TAM identifies perceived ease of use and perceived usefulness as key factors impacting technology adoption.
6. Perceived Characteristics of Innovation (PCI) (Moore, 1991): PCI focuses on innovation attributes like relative advantage, compatibility, complexity, and trialability.
7. Technology Readiness Assessment: This approach evaluates individuals' readiness to adopt technology based on their psychological and technological skills.

2.4 CRITICISM LEVELLED ON IMS THEORIES OF TECHNOLOGY ADOPTION

Even though the IMS-based technology adoption theories offer valuable insight into the technology adoption process, they face criticism for oversimplification and limited academic impact (Wei, 2019). While useful for organisational effectiveness, they lack a framework for responsible or people-oriented technology adoption, especially in the SA mining context (Wei, 2019). Although these models reveal factors influencing technology acceptance, they do not guide how to navigate the challenges of conflicting values and multi-stakeholder perspectives in technology adoption (Raza & Standing, 2010).

In acknowledging these limits, alternative theories from management science, ergonomics, and innovation have gained attention (Zulu et al., 2021). The following schools of thought are proving to provide alternative theoretical thinking to conventional IMS theories of technology adoption:

1. Ergonomics-based theories,
2. Human-centred design,
3. Responsible innovation,
4. Six sigma.

2.4.1 Ergonomics-Based Theories

Ergonomics contributes significantly to understanding technology adoption, focusing on integrating ergonomic considerations into technology design, particularly in mining. Extensive research on implementing ergonomics in mining is increasing (Sander and Peay, 1988; Simpson et al., 2009). Ergonomics theories of technology adoption stress integrating ergonomics principles into the design of mining technologies and responsible adoption of technology (Whitson, 2018). This aligns with Lind's (1991) theory of a development biased technology adoption and Bailey and Barley's (1991) unitary approach to technology adoption (Bailey and Barley, 2019).

Participatory ergonomics programmes and assessment tools are crucial for introducing autonomous and robotics technologies effectively (Sander and Peay, 1988; Simpson et al., 2009). Their importance in mining applications underscores the need for technology adoption strategies that enhance relevance and applicability (Whitson, 2018).

2.4.2 Human-Centred Design Theory

Human-centred design (HCD) theories of technology adoption draw from diverse disciplines, including design thinking philosophy, to humanise design. HCD theories centre on the importance of considering human factors when implementing 4IR strategies and technologies (Norman, 2013; Savolainen, 2021). Its focus on inclusivity suits responsible technology adoption compared to information management science-based theories.

However, Heenop et al. (2019) found limitations in HCD's maturity as a decision support framework for technology adoption. According to Heenop et al. (2019), integrating HCD processes hindered successful design outcomes, impacting its efficacy even in infrastructural projects. Although Grandi et al. (2020) argue for HCD's success in integrating natural, social, and engineering aspects, they also noted its limited practical application. Their research highlighted HCD theory's inability to effectively integrate human performance analysis and social impacts with technical issues in design, leading to criticism of its practical realisation.

2.4.3 Responsible Innovation Theory

Responsible innovation prioritises societal impacts and ethics in technology, focusing on reflection, stakeholder inclusion, and societal benefit (Jackobsen et al., 2019). It aims to tackle improving decision-making processes in relation to societal challenges brought about by technology.

It has been criticised for not providing practical tools to solve for inclusion of affected stakeholders when implementing technology rollout. It is thus hoped that in its mature state, this model will be able to address the importance of including affected stakeholders in research and innovation, not just those developing the technology. Future applications of responsible technology theories need to redefine responsibility, sparking discussions on societal benefits beyond academic theories (Jakobsen, Fløys & Overton, 2019).

2.4.4 Six Sigma Technology Adoption Model

Six Sigma methodology, known for process improvement, is becoming relevant for technology adoption decisions. Its focus is on sustainability, cost-effectiveness, and quality. It aligns with responsible and socially conscious technology adoption. Six Sigma helps organisations select and implement technologies that fulfil budget, schedule, and sustainability requirements (Antony, 2014).

2.5 TECHNOLOGY MANAGEMENT PROBLEM-SOLVING MODEL

Zulu, Pretorius, and Ven der Lingen (2021) conducted an integrative literature review on challenges facing South African mining companies in adopting 4.0 technologies. They offer an alternative view, emphasising the importance of problem-solving techniques as a prerequisite to solving for technology adoption. Their analysis highlights the need for a systematic process in technology adoption comprising problem identification, technology choice, solution development, implementation, and monitoring.

Their review notes that challenges identified in technology adoption lack alignment with the technology management problem-solving model in mining companies (Zulu et al., 2021). They stress the importance of categorising adoption challenges based on the technology management problem-solving model stages. Their Figurematic representation of this model underscores the significance of aligning technology adoption challenges in

SA mining with the technology management problem-solving model stages due to the distinct traits and attributes of each different stage of the problem-solving model (Zulu et al., 2021).

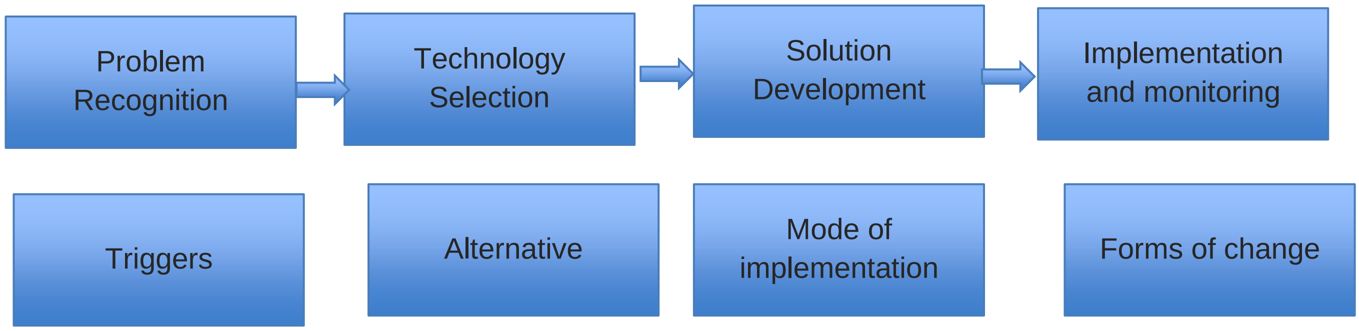

Figure 2-1: Technology Management Problem-solving Model (Zulu et al., 2021)

According to Zulu et al. (2021):

- The challenges associated with the problem recognition stage could result from not understanding the triggers of the problem and could include factors such as feasibility, market potential and mandatory constraints.
- In the technology choice stage, the challenges could be associated with design.
- Solution development problems could be related to innovation and adoption.
- The implementation and monitoring of the challenges could be more about reconfiguring the value chains and commercialising new technology products.

According to Zulu et al. (2021), academic literature on South African mining houses' adoption of technology is silent about guidelines and frameworks on the successful adoption of technology but sheds light on what success is in terms of technology adoption and how successful adoption of technology can be measured. According to Zulu et al. (2021), most of the drivers of the success in the adoption of technology by SA mining companies include the following:

- Organisational and customer issues
- Integrating physical and digital elements
- Leadership capabilities
- Digital strategy
- Awareness and Training

- Cultural change
- Creating innovative ideas
- Creation of additional value
- Sales and customer base
- Information and Communication Technology

Success factors approached purely from an IT perspective have proven to be failures (Zulu et al., 2021). Overall, the success of digital transformation initiatives can be based on operational efficiency and profitability (measured in earnings per share, operating profit margins and return on assets). However, for the South African context success of the digital transformation initiatives can be measured against dimensions relating to the major challenges that SA mines face:

- Improved safety, measured by a decline in fatalities, was reduced.
- Rate of time lost through injury.
- Reduce DMRE section 54s stoppages.
- Productivity (measured by enhanced revenue, increased throughput, increased equipment uptime and utilisation, reduced operating costs, (measured by higher equipment productivity. Reduced labour and consumables costs.
- Reduced waste generation.
- Reduced capital intensity (measured by reduction in asset /equipment damage).
- Improved life of mine and its reserves (measured by better and more reliable exploration data, feasibility of deep-level mining).

The success of the technology the adoption can also be viewed from the initiative's compliance and or success against project management protocols (cost schedule and delivery). However, it has been acknowledged that this dimension would be difficult to simply apply in the context of technology transformation due to the complexity of digital transformation projects. The adoption of technological transformation projects initiatives are by their nature very complicated that they warrant their own full project management approach (Zulu et al., 2021)

2.6 THEORETICAL IMPLICATIONS FOR THE RESEARCH STUDY

Each framework offers unique strengths that can enrich responsible and relevant robotics technology adoption amid Industry 4.0. Integrating these frameworks can provide a more comprehensive approach to tackling challenges in adopting robotics technology within the case study's context.

Table 2-1: Summary overview of IMS and new age thinking technology adoption theories **and their implications for the adoption of robotics technology**

Technology adoption Theory	**Implication to robotics technology adoption in AAPSP**
Diffusion of innovation Theory of reasoned actioned Theory of planned behaviour (TPB) Decomposed theory of planned behaviour Technology adoption model Perceived characteristics of innovation	These theories emanate from the discipline of information science and suggest that there are prevalent instrumental factors influencing both individuals and organisations in adoption of technology. Factors such as the perceived benefits, complexity, compatibility with existing systems, and observability. This allows for strategising of robotics technology and related early talent vision to be based on an information management system (IMS) perspective.
Technology readiness level (TRL) Theory	The TRL theory of technology adoption centralises the importance of measuring the maturity of a technology, ranging from 1 (concept) to 9 (commercialised product). The focus will be on solving for assessing the feasibility and risks of adopting the various applications of robotics technology depending on their maturity and to determine the appropriate stage of implementation of the different robotics technology applications.

Human Centred Design	Involves understanding the needs and perspectives of users and stakeholders when adopting robotics technology.
Lean Six Sigma	The adoption approach derived from the Lean Six Sigma provides a mechanism to adopt robotics to identify business improvement opportunities, reduce waste and to optimise efficiency.
Responsible innovation	Responsible innovation school of thought is an approach to innovation that considers the social, ethical, and environmental impacts of new technologies. This framework helps to ensure that the adoption of robotics technology is responsible and sustainable. Responsible innovation theory comes closest to providing platform for solving for relevancy, applicability and accountability (responsible) in technology adoption because it seeks to ensure that the benefits of its innovation are maximised while minimising its risks and negative impacts.
Technology management problem-solving model	Problems related to the adoption of technology are categorised as solution development stage problems.

The above theoretical positions are applicable in providing frameworks for assessing robotics technology adoption's benefits and risks; they are lacking in providing a framework that is able to take cognisance and provide guidance on ethical, social, and regulatory barriers to adopting technology (Lopez et al., 2018). Responsible innovation and technology management problem-solving models are the closest in providing some degree of relevance in prioritising relevancy, fit for purpose, applicability, conflicting values, inclusivity (involving diverse stakeholders), e.g. workers, regulators, and community members for technology alignment.)

They are the closest in addressing a people-centred robotics technology adoption strategy because of agility in anticipating challenges, identification and mitigation of risks and pre-the adoption for ethical implementation. Thirdly, both perspectives allow for monitoring of social, ethical, and environmental implications considering the technology adopted, therefore ensuring technology improvement and solving for applicability.

2.7 UNITARY APPROACH TO THE ADOPTION OF TECHNOLOGY PROVIDES A BASIS FOR RELEVANT AND SUSTAINABLE UTILISATION OF THE TECHNOLOGY

Bailey and Barley's (2020) unitary approach extends beyond technology's design and variation of use to include consideration of power, ideology, and institutional changes. It, therefore, offers comprehensive insights into technology's role in the power equation and societal role. According to Bailey and Barley (2020), discourse of current studies of AI, automation, robotics, and the future of work gloss over four important issues:

- Variation of use based on design,
- Power behind the technology,
- Ideology that encourages the creation and development of technology and
- Institution and societal changes brought about by the technology.

A unified approach to studying tech adoption emphasises a research-based foundation that coordinates variations in use with studies on power, ideology, design, and institutional change (Furman et al., 2016). It aids in shaping governmental policies to mitigate tech-driven unemployment.

The approach prioritises rethinking social programmes and institutions to address potential worker hardships in this transformed landscape (MCS, 2019; World Economic Forum, 2019; Lind, 1991; Einter, 2001). It delves into understanding the societal impact and ideologies driving technology.

Unlike other adoption theories, this approach eases the transition to underdevelopment theories, addressing fundamental issues. It scrutinises power dynamics, ideologies, and institutional shifts resulting from technology, guiding policies to counter technological unemployment's consequences. Insufficient research on these factors hinders responsible innovation, making a unified approach vital for equitable policies and programmes.

2.8 DEVELOPMENTAL BIASED THEORIES FOR TECHNOLOGY THE ADOPTION

Lind (1991) emphasises that technology solutions must align with reality. In a West African customs case, a system's flaw in reducing duty hindered the adoption, highlighting the need for recognising genuine problems in their real context when designing and implementing technology in the adoption roadmaps. Lind notes that success in developed economies might not apply in developing contexts due to differing norms. Addressing fit and conflicting values is crucial for technology adoption.

Developmentally biased technology adoption theories (Lind, 1991; Dimpsey et al., 2018; Whitson, 2018; Einterz, 2001) emphasise the importance of contextualising issues and reality to prevent misinformed strategies and offset development goals.

1. Whether the technology reflects the reality of the situation is the reality of the situation reflected in the 4.0 technology solution. If not, then the technology solution and related services become just a cosmetic or a nice to have.
2. Secondly, it is important to understand whether there is a lack of fit between the technology solution and the reality.
3. Thirdly, to understand the conflict between two values (the value system of the 4.0 technology solution and the value system that is on the ground).

Drawing from the above deduction, according to the developmental biased theories of technology, the adoption, addressing the above issues (relevancy, misfit, and conflict of values systems) and finding a solution to them will result in the adoption of technology in a manner that will lower various hindrances existing in utilising or taking up the technology. This position is also supported by the unitary approach to the adoption of technology(Bailey and Barley, 2019)

2.9 CRITICAL SYSTEMS THINKING: A THEORETICAL FRAMEWORK TO ADOPT ROBOTICS TECHNOLOGY AND DEVELOP ROBOTICS ADOPTION SKILLS

Minerals and metals from mining are crucial for a low-carbon future, yet uncertainties about the economic, environmental, and social impacts of the mining sector persist (Natalia et al., 2016). The mining sector continues to face complex challenges in social and human rights (Khubana, 2022). Amidst technological advancements, social and climate issues and transparency are becoming more vital for mining success (Deloitte, 2018; Khubana et al., 2022). Organisational policies and practices in mining are also increasingly being positioned to drive societal improvements, and environmental, social and governance (ESG) is becoming a new provision for a competitive edge in the mining sector (Porter & Kramer, 2011).

In addition, shared value (SV) creation in mining is also becoming a key component of competitive edge. It involves environmental solutions, employment enhancements, supply chain innovation, automation, infrastructure investment, and legal compliance (Cooper & Harvey, 2018; Porter & Kramer, 2011). Innovation in the mining sector is increasingly becoming about embracing complexity due to the need of the sector to have lasting impacts on its stakeholders (Ralston et al., 2017).

Automation, AI, and robotics technology are redefining traditional processes for social and economic benefits (Ralston et al., 2017). All the above considerations effectively render the practice of robotics adoption obliged to align with responsible mining, ESG goals and the creation of SV (Khubana, 2022). Essential skills for shared value-aligned robotics the adoption must be identified (McKinsey, 2019). Neglecting production revolution and sustainable development could cost jobs and revenues (Khubana, 2022). Human rights, social plans, ESG, and mining charter compliance are crucial components that the adoption of robotics needs to align with (Fraser, 2019). Socio-technical systems are key to automation success (Rogers et al., 2001). In addition, ethical and legal considerations are increasing with the use of robotics technology (Neale, 2019; Lopez et al., 2018).

Recently, Cosbey et al. (2019) reviewed the changing technological mining landscape through an SV paradigm. A key consideration of this study was the impacts of automation on various occupations. The study showed that automation will affect drilling, blasting, train and truck driving most significantly. These occupations account for more than 70% of jobs in a typical mine. These considerations are critical for examining technological change in the mining sector in terms of SV to stakeholders.

Zulu et al. (2021) also showed that there is a dominant view from scholars that when a mining company adopts technology, it should create additional value. Value creation is thus a critical dimension for achieving successful digital transformation (Hanelt, Hildebrandt & Kolbe, 2018; Moke, Brosi & Welp, 2020)

There is a belief that only a comprehensive approach that takes a socio-technical systems perspective can provide insights that will be critical for the successful implementation of automation. (Rogers et al., 2019). A multidisciplinary approach is needed to address the complexity of technology adoption (Jokonya, 2016).

Critical systems thinking addresses the integration of technical and social aspects (Jackson, 2010; Reynolds et al., 2010; Jokonya, 2016; Raza & Standing, 2010) and integrates stakeholder diversity and ethics in the adoption of innovative technologies (Jokonya, 2016). The increasing complexity and diversity of Information Technologies (IT) adoption in organisations require a multidisciplinary approach to understand its challenges (Jokonya, 2016). Critical systems thinking approaches improve IT adoption success in organisations because of their ability to address both technical and social issues (Jackson, 2010; Reynolds et al., 2010; Jokonya, 2016; Raza & Standing, 2010)

Most specifically, Jokonya's (2016) study on organisation's perception of the importance of CST in technology adoption showed the following results:

- Participants indicated that addressing both technical and social issues during technology adoption results in positive outcomes.
- Sixty-two per cent of the respondents agreed that stakeholder diversity is important in technology adoption.
- 85 per cent of the respondents agreed that it was important to address critical issues during technology adoption compared to those who disagreed or were neutral.

- Seventy per cent agreed that it was important to address ethical issues during technology adoption compared to those who disagreed or were neutral.
- More than half of the respondents agreed that it was important to emancipate stakeholders during technology adoption in organisations.

Overall, the study contributed to the importance of CST in technology adoption. This is the rationale behind comprehensive ICT adoption approaches such as CST-based systems development life cycle (SDLC). CST-based SDLF supports smooth IS adoption (Raza, 2010). The success of automation and robotics implementation depends on transformational processes, not just technology (Wood and Sanders, 2020). The success of WeChat's AI stems from design thinking, understanding users, challenging assumptions, and innovation (Birkanshaw et al., 2019). The key components driving the success of the AI-driven WeChat approach are aligning human, technological, and economic perspectives, empathy, collaboration, and strong leadership (Birkanshaw et al., 2019).

2.9.1 BENEFITS OF USING CRITICAL SYSTEMS THINKING IN ADOPTION OF ROBOTICS TECHNOLOGY

Critical Systems Thinking (CST) offers a holistic approach to adoption of robotics technology (Munneb,2024). This is because CST allows capability of viewing robotics development and adoption as part of a larger system rather than in isolation. CST promotes understanding of the interconnectedness and interdependencies within systems, leading to informed decisions on robotics adoption. It encourages cross-functional collaboration, long-term process improvement, and smooth transitions by addressing resistance to change and fostering communication.(Aivazidou & Tsolakis, 2023; Hamidi, Mirijamdotter & Mildrard 2023)

2.10 USE OF CRITICAL SYSTEMS THINKING THEORY AS A FRAMEWORK FOR ADOPTING A RELEVANT, RESPONSIBLE MINING-BASED ADOPTION STRATEGY

Application of Critical systems thinking in robotics technology adoption implies investigating and surfacing underlying powers, ideologies, and worldviews driving the robotics technology applications within real-world contexts (politics, economy, social).

It establishes relevance within specific worldviews, clarifying purpose and values, and then deploys methodologies to design processes, structures, and systems, including appropriate robotics technology variations for achieving relevancy.

Beyond problem surfacing, critical systems thinking ensures fit for purpose implementation and skills alignment for robotics technology. It advocates a unitary approach to the adoption, emphasising analysis of the powers and ideologies driving the intention, intelligence, and technology design. This is a crucial yet often overlooked aspect in studying and adopting Industry 4.0 technologies like automation and robotics.

Key attributes of critical systems thinking that are relevant to robotics technology adoption include:

- Diversity driven decision-making, considering various dimensions of issues from design nature intent to moral concerns.
- Preservation of complementarity (holism) in both theory and methodology (Gregory, 1991).
- Total Systems Intervention (which is a CST application tool) embodies practical critical systems thinking, promoting complementarity, sociological awareness, and commitment to human well-being and emancipation (Flood, 1995).

2.11 SYSTEMS THINKING: THEORETICAL UNDERPINNINGS OF CRITICAL SYSTEMS THINKING

Churchman's works, notably "The Systems Approach and Its Enemies" and "Design of Inquiry Systems," provide valuable insights into systems thinking. The "Design of Inquiry Systems" highlights nine essential conditions, as articulated by Churchman (Checkland, 1988), that must be met for something to be considered a system (S) the most important being the following:

- S has a purpose (teleological).
- S has a measurable performance.
- A client with vested interests (values) is served by S.
- S comprises purposeful components.
- S operates within an environment.
- A decision maker can influence S's performance.

- A designer conceptualises S to prompt actions in the decision maker, leading to changes in performance.

Critical systems thinking focuses on understanding how interactions among components shape system outputs (Raza & Standing, 2010).

Systems have boundaries and exist within larger environments, often acting as subsystems. Interactions among parts create dynamic characteristics absent in isolated components. Systems thinking emphasises recognising the collective intensity, reality, and meaning of these interactions. Fuenmayor (1991) notes that a systems approach seeks holistic understanding, defining systems as more than just collections of parts. The ontological proposition of systems transcends mere aggregation. Epistemologically, systems view phenomena as transcendental wholes, not just aggregates of parts (Fuenmayor, 1991).

> *"The quest of the systems approach study phenomena as if they were transcendental wholes and not mere aggregates of the parts, thus as systems approach focuses on holistic sense of the phenomena" (Fuenmayor, 1991, page 423)*

2.11.1 Comprehending the Whole Versus Analysing the Parts

Science dissects parts to understand fundamental building blocks but falls short in revealing potential interactions and environments. Analytical thinking aids prediction but has limits in revealing interactions' potential forms. CST views phenomena as holistic entities, acknowledging emergent wholes from interactions. It suggests that the whole's identity encompasses infinite possibilities driven by constituent parts. Fuenmayor argues that emergent characteristics cannot be lab-analysed like individual parts. Microscopy yields part details, needing a distinct approach to study the whole's real existence and infinite potential from interactions.

Systems, much like their parts, engage in various relations and reactions defined by their composition. The entirety of a system can adopt multiple identities shaped by these interactions. Understanding systems, especially through systems thinking, proves more challenging than analytical thinking. While dissecting individual components is straightforward, systems hold diverse meanings for different observers. Social systems, like all systems, rely on context and assume diverse forms. However, this diversity does not negate the possibility of understanding them. Grasping a system requires adopting a specific view rooted in theory. Confidence in comprehending a system's nature guides study and intervention methodologies.

2.12 CRITICAL SYSTEMS THINKING: ADDRESSING SYSTEM DIVERSITY AND DEALING WITH COMPETING PARADIGMS

2.12.1 an Answer to Solving for Relevancy, Fit for Purpose and Conflicting Values

Systems practice seemed for a long time to be scattered due to diverse methodologies and conflicting conceptions, fostering competition among practitioners (Oliga, 1988). Soft system methodologies focus on resolving conflicts for consensus, while hard systems methodologies presume the resolution of such problems, leading to rigid thinking. In addition, paradigm incommensurability creates challenges in unifying dominant paradigms, hindering a cohesive language for systems practice.

This incommensurability means each paradigm's statements hold legitimacy but cannot be directly compared, leading to isolationist or stereotypical stances. This discourages systems thinking, resulting in isolated, reductionist practices failing to address system complexities comprehensively.

In the 1980s, critical systems thinking (CST) emerged, marking a more complete approach. CST aimed to respect systems as a transcendental whole rather than through varying perceptions. It sought a foundation enabling diverse paradigms' use to understand systems, affirming systems practice's potency despite paradigm diversity and challenges.

2.12.1.1 Principles of Critical Systems Thinking

CST is a research perspective which embraces a set of five fundamental commitments.

1. Firstly, CST emphasise the importance of critical reflection,

2. Secondly, CST emphasises the need for awareness. This means awareness of the trends of the time or, to be more specific, the methodologies which are more likely to be favoured, especially by those in power at the time of intervention in a system and an awareness of the consequences of going along with the trends as opposed to not.
3. Thirdly, CST is committed to human emancipation and advocates that interventions should be done to emancipate and better the conditions of human life,
4. Fourthly, it is based on and committed to complementarianism at a theoretical level.
5. Fifthly, CST emphasises complementarism at a practical level. Commitment to complementarism at both theoretical and practical levels in CST is made possible by a need for holism in human cognitive evolution and, as such, a need for holism in the development of social systems.

2.12.1.2 Pluralism in Critical Systems Thinking

CST promotes diversity by uncovering various perspectives in a situation, termed critical awareness (Flood & Jackson, 1991). It challenges assumptions, aiming to reveal multiple valid positions and create new mental models.

It emphasises emancipation and power dynamics, focusing on local improvements. Flood (1990) explored systems approaches and found pluralism most effective for long-term survival. CST advocates understanding alternative positions over isolationism, suggesting a comprehensive vision rather than merging theories. Instead of isolationism, CST favours methodological pluralism, viewing methods as valid tools rooted in theory. Midgley (1991) proposes discordant pluralism, drawing from different paradigms within a new constellation. CST challenges reductionism, prioritising plurality and comprehensive vision.

Methodological pluralism in CST involves applying diverse methodologies contextually, understanding each within its theoretical context for mutual learning (Flood & Jackson). The system of systems methodology suggests using hard and soft methods based on goal agreement. CST advocates a holistic approach, integrating both hard and soft dimensions for critical systems rationality.

2.12.1.2 Total Systems Intervention 1

The primary rationale behind CST is the use of complementary systems methodologies for a comprehensive understanding and effective intervention in systems. The CST-influenced methodology known as Total Systems Intervention (TSI) facilitates this concept of complementarism in two ways:

1. TSI enables practitioners to perceive systems from various perspectives, achieving theoretical complementarism.
2. TSI offers a technique for practitioners to use different systems methodologies harmoniously, confirming meaningful intervention and methodological complementarism.

TSI involves two main components:

1. System Nature Decision: The practitioner determines whether the system is complex or simple and assesses participants' relationships (unitary, pluralist, coercive). Metaphors that best describe the system are also considered to ensure a holistic view. This decision informs the overall nature of the system, guiding how it should be studied.
2. Methodology Choice: Using the system nature decision, practitioners select an appropriate intervention methodology. The system of systems methodology matrix aids this decision by identifying relevant methodologies based on the problem context.

Previously, the use of the system of systems methodology matrix was critiqued for appearing functionalist, as it seemingly involved arbitrary selection. Critics argued that the matrix did not account for the subjective nature of methodology choice, dependent on the observer's perspective.

2.12.1.3 Total System Intervention 1

LSI, known as TSI II, complements Total System Intervention (TSI) by embracing diverse theoretical backgrounds. It surpasses reliance on metaphors and the system of systems methodology matrix, navigating the “how,” “what,” and “why” paradigms of a system in a more complementary manner. It broadens system thinking by encompassing functionalist, humanist, and emancipatory perspectives. LSI moves beyond theoretical pluralism, offering inter-paradigm insights beyond metaphors. Once a methodology is chosen, LSI ensures alignment with CST principles through a reflective evaluation process.

2.12.1.4 TSII in focus

Local Systemic Intervention (LSI) stems from postmodern critiques of CST, serving as a creative problem-solving tool. It aims to generate locally relevant solutions considering various problem dimensions. Unlike critical systems heuristics, LSI expands beyond “why” and “how” to encompass design, intent, and morality.

LSI aims to establish actionable frameworks engaging with design, intent, and spirituality discourses. Despite the complexity of decision-making across these dimensions, LSI ensures a holistic approach. Its three phases—Creativity, Choice, and Implementation—involve breaking assumptions, selecting methods, and applying them. These phases work within three broader modes: critical review, problem-solving, and critical reflection.

The critical review assesses methodologies for potential intervention, categorising their contributions to problem-solving. Problem-solving involves incorporating methods addressing design, efficiency, decision options, and group interests.

2.12.1.5 Comprehensive Approach to Solving for Relevant and Responsible Adoption of Technology

To address multifaceted issues such as emancipation, pluralism, and efficiency, diverse perspectives and inclusive solutions are crucial. CST embraces trans-disciplinary methods, apt for complex scenarios like 4.0 technology the adoption challenges.

Traditional scientific methods overlook social aspects, but CST integrates critical awareness, social understanding, and theoretical pluralism. It encourages multiple perspectives and methodologies suited for technical, social, and political complexities in organisations (Jackson, 2010; Cordoba, 2009).

Soft system thinkers face limitations in conflicted or resource-unequal scenarios. Emerging methodologies like systems dynamics, organisational cybernetics, and complexity theory respond to the failures of traditional and hard systems approaches in handling complexity and human/social aspects. Emancipatory systems thinking (CST) challenges inherent conservatism in methodologies. CST advocates considering perspectives from functionalist, interpretive, emancipatory, and postmodern paradigms to understand complex problems comprehensively.

The practitioner must bring radically different worldviews derived from various paradigms to appreciate complexity. CST suggests analysing problem situations from multiple paradigms before narrowing them down to crucial aspects for intervention. This involves reviewing the strengths and weaknesses of different methodologies to choose suitable interventions.

Implementation proceeds by employing the dominant chosen methodology and methods. As the intervention proceeds, the problems that earlier seemed to be crucial may fade into the background, and new ones emerge. This can be catered for by continually cycling around the phases. Reflection seeks to judge how successful the intervention has been in bringing about improvement. It does this by considering what each paradigm rates as the most significant.

- Functionalist paradigm prioritises goal seeking and viability, judging in terms of efficiency and efficacy.
- Interpretive paradigm prioritises exploring purpose by enhancing mutual understanding judging in terms of effectiveness and elegance.
- Emancipatory paradigms seek to ensure fairness, judging in terms of empowerment and emancipation.
- The postmodern paradigm values the promotion of diversity, judging in terms of exception and emotion.

A highly successful intervention should be able to demonstrate progress on all these fronts. Although it might look difficult, managers working in socially designed institutions such as organisations are finding that the circumstances they are dealing with are becoming even more difficult, turbulent, and complex. CST provides a common sense approach and is in tune with common sense (Jackson, 2010). It recognises that excellent organisational performance depends on managers paying attention to improving goal seeking and viability, exploring purpose, ensuring fairness and promoting diversity (Jackson, 2010)

2.13 SKILL CHALLENGES FOR ADOPTING ROBOTICS TECHNOLOGY

The issue with skills is not just due to education and technology use but hindered technology utilisation (Kamaruzaman et al., 2019; Lind, 1991). Competencies in addressing relevancy, fit, and conflicting values directly impact technology adoption challenges. Development and unitary theories and the technology change problem-solving model emphasise this link (Zulu et al., 2021). Addressing this requires skills at the problem recognition stage and understanding the structural nature of technology adoption issues.

CST equips practitioners to surface issues from various worldviews. CST skills are crucial in developing relevant, conflict-resolving technology adoption strategies, particularly in South Africa’s mining industry. Solving for relevancy, misfit, and conflict issues optimises robotics technology use and minimises hindrances to technology adoption. Developing skills is not just about developing technical competencies in the use of technology but also developing competencies in the ability to understand and define relevancy and fit for purpose (Lind, 2021; Bailey & Barley, 2020).

Skills in unpacking conflicting values, addressing misfits, and defining relevancy are vital for effective robotics technology utilisation in mining. The unitary approach similarly stresses the need for skills that identify relevancy and fit for purpose in the mining sector. Both a development-based and unitary approach to technology adoption implies the need for skills in the mining sector that have the capability to surface problems situation in light of the following socio-economic realities:

1. National development plan.
2. Spatial development framework.
3. Contextual integrated development plan from which the mining operation operates.
4. Mining charter, transformation goals, ESG goals.
5. Skill development framework.
6. Productivity safety.
7. Robotics technology application (teleoperations, etc.).
8. Mining company organisational change dynamics.
9. Early talent and leadership development.
10. Impact on the host community (economy, SMME development, community skills).
11. Societal impact and changes (loss of jobs, youth unemployment, effect on family).

Unpacking the ideologies behind robotics technology design lays the foundation for understanding relevance in any system or context and, therefore, becomes the basis for revealing diverse worldviews. Understanding these worldviews equips technology adopters and learners to assess the technology's applicability in context. These skills are not technical but fall under the umbrella of soft skills crucial for supporting the 4.0 revolution. Grand challenges like energy, water, and food scarcity demand solutions beyond simple cause and effect, requiring students to apply holistic approaches (Gilbert, 2018).

Jackson (2010) summarises the skills that cut across a critical systems thinker to include amongst other the following:

1. Critical systems researchers do not claim to know the answer in advance.
2. Nor do they peddle the same solution to all problems in all circumstances.
3. Critical systems researchers seek to be holistic, and they ensure that theory both underpins practice and is tested in practice.
4. Critical systems thinkers are clear that they should ask, as part of their project, who benefits from the knowledge and advice provided?
5. They put Ethical issues firmly on the agenda.

6. They test the diversity of the tools available for use (from the systems approach and the management sciences generally) in the service of different rationalities.
7. They clarify the constitutive roles of functionalist, interpretive, emancipatory, and other forms of intervention.
8. They learn how to facilitate reflective conversation at the meta-methodological level.

The soft skills completing the above first order of skills include the below (World Economic Forum, 2021).

1. Leadership, management, and soft skills: to allow the ability to deliver and apply CST and local systems intervention.
2. Creativity: Creativity is the ability to generate and recognise new ideas, to do things, and to solve problems. Robots and AI cannot compete with human beings in being creative. The future will need new ways of thinking.
3. Emotional intelligence: Robots and AI applications do not have the ability to express and be cognisant of others' emotions. Empathy, integrity, and ability to work well with others.
4. Critical Thinking Skills: Necessary to navigate the human-machine relation and collaboration for improved productivity.
5. Active learner mindset: Capabilities to actively learn and grow. People with a growth mindset are willing to take on new challenges, learn from mistakes and actively seek new knowledge.
6. Judgement and decision-making: Human decision-making will become more complex as machine-driven information processing will continue to evolve and be complex. Machines will not be able to make judgement (human judgements)
7. Interpersonal communications: communicate and exchange information and meaning between people.
8. Leadership: ability to inspire, help and motivate. Identify talent and do better for the good of the bigger picture.
9. Diversity and cultural intelligence: ability to understand, respect and work with others who have a different way of seeing things.
10. Technological skills: at some point, it will be important to be confident and comfortable around technology.

11. Embrace change: the ability to be agile, embrace and celebrate change.

Automation and robotisation bring about the need for new set of skills and diverse knowledge which constitutes new challenges for today's industries (de Holando, 2024) . According to a study conducted by Purwanto, Hartono & Wahyuni (2023), by 2030 there will likely be a competence gap in the youth of today . The 4IR generation teacher's role is to build a generation of learners with competence , character, new literacy skills and higher order thinking skills (Purwanto, Hartono & Wahyuni, 2023). These skills are inclusive of the creative aspects, critical thinking , communication and collaboration.

A study by Miah, Erdie-Gally, Dancs & Fekete-Farka (2024), indicated that the top skills and skill sets expected to be increasingly in demand from 2023 to 2030 are those indicated below :

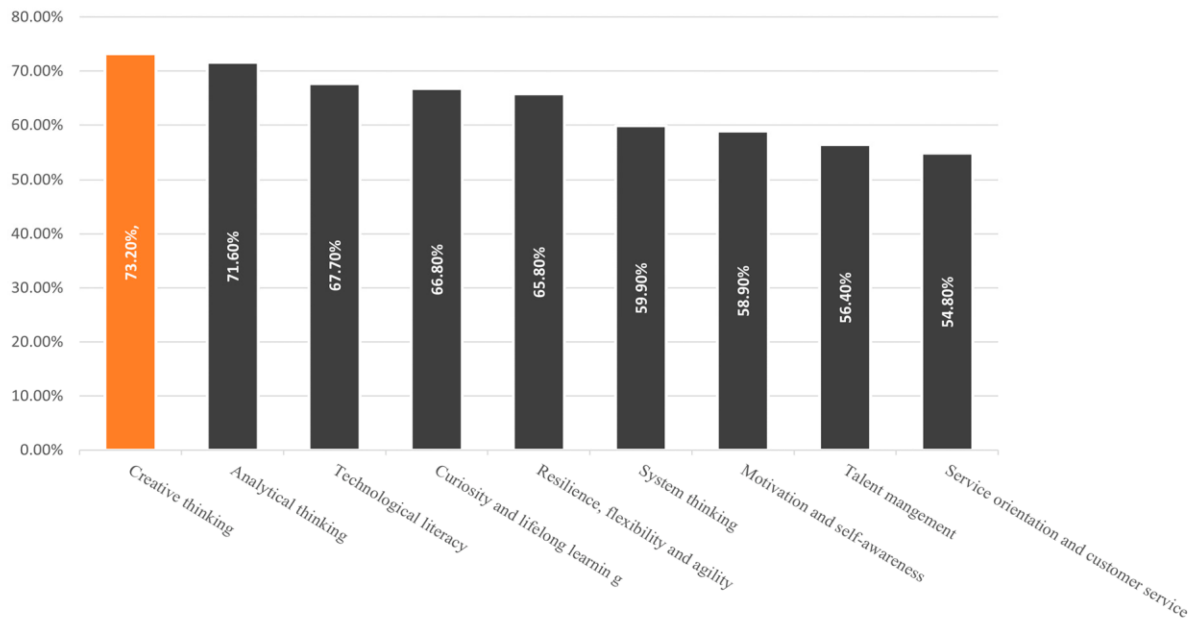

Figure 2-2 Top 10 skills in demand according to the World Economic Forum. Source: Miah, Erdie-Gally, Dancs &Fekete-Farkas;2024)

According to the bove , creative thinking is expected to grow faster in the next five years than demand for analytical thinking (Miah, Erdie-Gally, Dancs & Fekete-Farkas, 2024) The above emphasises the importance of strategies for adopting new skills in developing countries and reforming education with enhanced training curricula). The conceptual framework proposed by Miah, Erdie-Gally, Dancs & Fekete-Farkas (2024) suggest specific capabilities and skills which include technical skills, digital skills, cognitive skills as the future workforce and individual skill need to effectively operate and manage AI automated operations.

Successful implementation of robotics, such as in zero-entry mining, requires a workforce skilled in supporting, maintaining, and repairing autonomous systems. Australia has established a Certificate IV in Industrial Automation and Control, training individuals in various technical skills necessary for maintaining automated systems. (Knights & Yeates , 2021). However, there is a noted gap in academic literature on enhancing Critical Systems Thinking based digital competence and computational thinking skills, especially among K-12 students preparing to enter the computational workforce. (Knights & Yeates , 2021)

There is according to Aivazidou & Tsolakis (2023) an urgent need to strengthen digital based curriculum revitalisation. Curriculum revitalisation should be integrated to to the basic values of resilience, adaptability integrity, competence and continuous improvement (Purwanto, Hartono & Wahyuni, 2023). Khan & Bari (2023) also shed light to the notion that in curriculum revitalisation , the robot is not the end of enhanced learning , the real problem is not the robot , the robot is just another tool (Khan & Bari 2023).

An appropriate education philosophy is the most important factor that can lead to the success of robot development and robot adoption (Ching, & Hsu, 2023; Khan & Bari 2023). The goal is to create a generation of high level competence character and literacy to answer the challenges of the industrial revolution era .

2.13.1 Problematising Computational Thinking(CT) through Systems Thinking (ST) and Critical Systems(CST) lens : an approach towards application of CST in robotics adoption

The integration of Systems Thinking (ST) with Computational Thinking (CT) offers a comprehensive approach to training and development (Hamidi, Mirijamdotter & Mildrard

2023) While CT has been traditionally focused on algorithmic thinking and problem-solving that computers can execute, it is now now recognized as a vital skill across various disciplines, not just computer science. Systema Thinking (ST) particularly Critical Systems Thinking (CST), is seen as a valuable complement to CT, addressing its limitations by adding behavioural and societal considerations (Adnan, Abdulla, Yusof, Zainal, Quamar & Yadegaridehkordi, 2023)

CT's core concepts like abstraction, sequences, loops, parallelism, conditionals, and data manipulation are now paralleled with fundamental literacy skills in K-12 education, especially within STEM subjects. ST, on the other hand, provides a framework for understanding complex phenomena and planning future actions. Its central concepts include emergence, holism, modelling, boundaries, and complexity.

The Distinction, System, Relationship, and Perspective (DSRP) rules of ST offer a holistic method for tackling real world complexities, enhancing conventional thinking skills like CT, and making them more effective in addressing real-world challenges. Therefore ,viewing CT through the lens of ST reveals hidden complexities and issues, particularly in how CT is applied within Computer Science (CS).

CT has been criticised as being overly reductionist, breaking down problems into parts without considering broader perspectives, leading to superficial solutions for complex real-world systems (Hamidi, Mirijamdotter & Mildrard 2023; Melro, Fujita, & Kleine, 2023; Santos, Phelps, &Yadav, 2023) . Reductionism opens a problem to be deconstructed into its constituent parts with a causal and straightforward connection . This unfortunately encourages surface level thinking which is inappropriate when dealing with complicated systems in the real world (Hamidi, Mirijamdotter & Mildrard 2023)

Scholars have raised issues and concerns about CT reductionism and suggested that integrating ST with CT can address these limitations, particularly by incorporating sustainability thinking, a conceptual framework for understanding change in complex systems, and fostering critical thinking beyond immediate technological functionalities. (Hamidi, Mirijamdotter & Mildrard 2023; Melro, Fujita, & Kleine, 2023; Santos, Phelps, &Yadav, 2023)

The key gaps in CT that could be improved by integrating with ST include:

- Sustainability ontology: Currently absent in CT, this would provide a framework for sustainable problem-solving.
- Conceptual tools: Needed for reasoning about changes in complex systems.
- Critical thinking: Encouraging deeper analysis of the broader impacts of technology.

The proposed solution is a shift towards holistic problem-solving that considers non-computational aspects such as social issues, ethical dilemmas, and judgment. ST and CST offer a theoretical foundation to address the pitfalls of reductionism and dogmatism in CT, advocating for a systematic approach to thinking that encompasses the interconnectedness of variables and multiple perspectives

2.13.2 Integrating CT into STEM education

The educational approach known as CT2.0 integrates Computational Thinking (CT) into STEM education, addressing the limitations of traditional CT by incorporating Systems Thinking (ST). This new taxonomy includes data, simulation, problem-solving, and ST practices, fostering inductive reasoning and context-aware problem-solving. By engaging K-12 students in systems modelling, CT2.0 blends ST's holistic perspective and CT's analytical methods, promoting a more practical and inclusive approach to education that prepares students to tackle both local and global challenges.

The academic integration of Systems Thinking (ST), Critical Systems Thinking (CST), and Computational Thinking (CT) is limited. Be that as it may , ST remains essential within CT practices, enhancing problem-solving by considering the complexities of systems (Hamidi, Mirijamdotter & Mildrard 2023; Melro, Fujita, & Kleine, 2023; Santos, Phelps, &Yadav, 2023

Two approaches are highlighted:

Incorporating ST within CT: This empowers multi-level thinking and helps students understand and solve problems by viewing the underlying systems.

Supplementing CT with ST: Termed 'critical computational thinking', it develops awareness of the societal implications of technology and includes understanding complex systems, relationships, and managing complexity.

Studies show that CT and ST are mutually reinforcing, with ST serving as a tool to enhance CT in STEM education. Researchers are urged to address the reductionist nature of CT and to broaden its contribution from other fields. The development of K-12 education in CT is currently focused on educational robotics, considering various perspectives. ST is increasingly seen as a cognitive skill, not just a methodology. It involves high-order cognitive abilities to understand and apply systems thinking. Presenting ST as a cognitive skill can democratize the discipline, promoting holistic flexibility among practitioners to manage variables and stakeholders effectively.

A conceptual framework for CST skills development in mining engineering has identified essential skills for the adoption of emerging technologies. These skills, recognized by engineering accreditation bodies, include communication, teamwork, ethics, lifelong learning, problem solving, management, technology, decision making, critical thinking, and leadership.

These skills are however deemed insufficient for the demands of the Fourth Industrial Revolution (4IR).and the World Economic Forum (WEF) has indicated that many current skills will become obsolete (Miah, Erdie-Gally, Dancs & Fekete-Farka, 2024). Academic arguments points to the the fact that there will be a significant shift in the skills in demand with skills in leadership, social influence, and problem solving, becoming more preferred.

2.14 DISPLACEMENT OR REINFORCEMENT OF SKILLS AND EMPLOYMENT LEVELS

Ndlovu, Ngwane and Mongae (2022) suggest that South Africa's mining sector's political settlement will significantly shape the adoption of 4IR technologies, influencing its process and extent. The advent of 4.0 technologies triggers debates on labour implications, with arguments divided on potential worker displacement through task simplification into computer algorithms (Ndlovu, Ngwane & Mongae, 2022). There are also arguments that technology's impact on workers balances between displacement and reinstatement effects. Displacement involves technology taking over human tasks, while reinstatement creates new tasks favouring human advantages (Acemoglu & Restrepo, 2018).

In the SA mining sector, adopting robotics technology may weaken trade unions, strengthening already powerful mining companies. This digital transformation might strain the alliance between trade unions and the ANC government, impacting the ANC's government's ability to mobilise electoral support.

2.15 CONCLUSION

This chapter reviewed technology adoption theories. No specific science of technology adoption was found. However, the research drew from conventional IMS theories of technology adoption to organisational effectiveness, ergonomics, and system science-based theories to anchor a theoretical base for a people-centred technology adoption strategy. The dominant theories, like TRA, TPB, TAM, DOI, and PCI, are criticised for oversimplification and neglect of crucial aspects like power dynamics, conflict, and human factors, leading to technology adoption failure (Wei, 2019; Yardley, 2002).

In the context of responsible mining, development theories highlight shortcomings in conventional adoption theories by emphasising relevancy and accountability (Lind, 1991; Dimpsey et al., 2018; Whitson, 2018; Einterz, 2001). Even basic frameworks like TRA, TPB, and TAM recognise that technology adoption requires integration between human factors, technology, and organisational culture (Barney, 1991; Mata, 1995; Ong, 2008; Tippins, 2003).

This study seeks theoretical positions aligned with responsible mining and technology adoption, similar to the unitary approach. It criticises existing theories for lacking academic innovation in technology adoption (Ong Jeen Wei, 2009; Bailey & Barley, 2020). Conventional theories and approaches to technology adoption are limited in that they mostly cater for a functionalist perspective, compromising the power of viewing robotics technology from the interpretive, emancipatory, and postmodern perspective and hence rendering the adoption strategy not fit for serving responsible mining and people-centricity.

This requirement also implies the need for skills in the mining sector that are not only focusing on the various applications of the robotics technology but are capable of applying CST, particularly the ability to deploy local system intervention and achieve a unitary approach to robotics application to guide relevancy and achieve responsible mining.

The chapter underscores the necessity of questioning the applicability of Western-developed technology models in developing countries, advocating for critical debate and contextual applicability. The current approach to adopting robotics often mirrors an imitation process, replicating both equipment-handling skills and conceptual thinking from Western models (Linde, 1991). CST, driven by soft skills and effective leadership, challenges this imitation and ensures relevant and sustainable robotics adoption (unitary approach).

The unitary approach provided a theoretical foundation for this study to advocate for CST in robotics adoption. CST tackles relevancy, fit for purpose, ethical, social, and regulatory challenges faced by the mining sector (Lopez et al., 2018). CST offers problem-solving techniques addressing relevancy, fit for purpose, SV, and responsible mining (Cooper & Harvey, 2018; Porter & Kramer, 2011; Khubana, 2022; McKinsey, 2019; Ralston et al., 2017).

CHAPTER 3 – RESEARCH METHODOLOGY

3.1 INTRODUCTION

The previous chapter delved into technology adoption theories, shedding light on various frameworks that elucidate the intricacies of technology adoptions and related innovations in addressing the skills required to successfully implement critical systems when adopting robotics technology. The review established a foundational reference point for understanding academic discourse on technology adoption, setting the stage for the subsequent exploration of robotics technology adoption challenges in the mining sector and specifically in the case of Anglo American Platinum School Project.

The main reflection that came out of the review of literature is that the dominant or conventional theories about the adoption of technology mostly come from the information systems field and are based on psychological sciences. It also became apparent in the last chapter that these theories do not provide strong academic reasoning for solving for achieving responsible mining, relevancy, accountability, and applicability in the adoption of technologies. Interestingly, development-based theories and management science theories are the ones that have provided a strong theoretical underpinning for responsible and relevant adoption of technologies.

Alternative theories from development theory, ergonomics, organisational effectiveness, and system science provided not only a stronger argument on solving for relevancy and sustainability but a foundation for exploring thinking about the relevant skills for ensuring a responsible adoption of technology and better theoretical basis for revolutionary skills required to achieve successful adoption of robotics technologies. The main conclusion derived from the literature review is that critical systems thinking provides a comprehensive and solid basis for robotics adoption success predominantly because of its ability to address technical, social, emancipatory, legal, and ethical issues relevant to the mining industry (Jokonya, 2016). The trans-disciplinary nature of CST allows the use of different approaches, methodologies, and methods in a complex robotics adoption problem situation (Jackson, 2010; Reynolds et al., 2010).

This chapter focuses on the research approach, methodology, techniques, and tools the research used to practically study how the adoption of robotics technology can be implemented in a responsible and relevant manner. The chapter looks at the methods used for the adoption of robotics technology and how the skills challenges of adopting robotics technology have been explored and addressed from a practical perspective. It defines the reason for using the case study approach and qualitative technique methods of collecting data and outlines how the qualitative data collection was implemented.

3.2 INTRODUCING THE CASE STUDY

The mining industry is moving toward automation for efficiency and safety. Anglo American Platinum (AAP) is following suit, expecting a faster transition with proven, affordable technology. AAP’s robotics adoption aims for responsible implementation, preventing widespread unemployment and negative local economic impact (Minerals Council, 2015). Skill challenges are rooted in an insufficient education system and the need to replace scarce quality skills with technology. Addressing hindrances in technology utilisation, like irrelevance and lack of fit, is crucial for successful implementation (Lind, 1991).

In order to adopt robotics sustainably, AAPSP must focus on skills solving for relevancy and responsible implementation. It is not just about achieving design goals but also positively impacting institutional and societal changes resulting from AAP mining operations. Sustainable robotics adoption requires strategies considering the social, ethical, legal, and governance implications. Future talent pipelines and reskilling programmes should support robotics adoption by comprehensively analysing the power, ideologies, design, and societal changes accompanying automation and robotics.

3.4 RESEARCH APPROACH

3.4.1 The Research Onion

In describing the methodological underpinning of this study, the writer followed the framework of the research onion. The research onion was created by Saunders et al. (2019). The interpretivism philosophical stance was adopted for this study because of its emphasis on the importance of understanding people's beliefs and motives. The approach used was the inductive approach, which involves extrapolating general truths from cases or observations.

The qualitative method was chosen for this study, which does not rely on numerical data and includes interviews, observations and open-ended surveys. The study was a short-term case study research that aimed to investigate issues related to the utilisation of technologies in developing countries. A case study approach, using qualitative data collection tools, was opted to research exploring the skill challenges related to relevant and responsible adoption of robotics technology.

The AAP's school project strategy was used as a case study to investigate the benefits of using critical systems thinking in addressing skills challenges of adopting robotics technology and how a CST-based early talent strategy can address skills required for responsible and relevant adoption of robotics for future mechanised, digitised and modernised mining. A case study methodology has been found to be a viable research strategy in information systems because of its in-depth approach.

This confirmed Oates'(2009) sentiment that, the case study research approach provides an opportunity for the researcher to understand normally inaccessible phenomenon (Oates, 2009). A deep inquiry process by means of one-to-one interviews with relevant management in the case study was conducted. These one-to-one dialogue processes were used as a research tool (and a creativity phase technique) for gaining reference to as many facets of challenges and opportunities, including skill challenges prioritised when laying the foundations of early talent in the adoption of robotics technology.

The interviews have been structured in such a way that the dialogue between interviewee and interviewer was not simply about getting information flowing one way (either from the interviewer to the interviewee or vice versa.) but was a process through which preconceived ideas about the adoption of robotics and resultant skill challenges were surfaced, interrogated and challenged. Challenging preconceived ideas on problems and generating new ideas was envisaged to achieve a means for surfacing core issues of concern regarding skill challenges and agreeing on priority issues of concern in a critical and creative manner.

3.4.2 Philosophical Stance

The chosen philosophical stance for this study is interpretivism. This research paradigm emphasises understanding individuals' beliefs, motivations and thought processes to interpret collected information about a subject. Interpretivism values diverse paths to knowledge and utilises strategies that uncover truth. It leans toward a qualitative approach and prioritises contextual insight.

3.4.3 The Approach

The data analysis method establishes a theoretical framework for practice, including three main approaches: induction, deduction, and ablation. For this study, the researcher opted for the inductive approach.

Induction involves deriving general truths from specific cases or observations. It starts with observations and eventually develops theories based on these findings. Through successive hypotheses, inductive inquiry seeks patterns from observations, leading to explanatory theories (Bernard, 2011). In this inductive study, the researcher enjoyed freedom from constraints. Inductive studies allow flexibility to adjust the study's direction once it is underway.

3.4.4 Strategies

The study employed the qualitative method due to its aptness for comprehending underlying reasons and people's opinions on specific issues or problems. This approach facilitated the researcher's goal of understanding these aspects.

Unlike quantitative approaches, the qualitative method does not depend on numerical data. The collected data was non-numerical, offering valuable insights into the research problem and effectively achieving the study's objectives. The methods utilised encompassed interviews, observations, open-ended surveys, and focus group discussions.

3.4.5 Case Study Research

The case study research method, as outlined by Yin, investigates contemporary phenomena within their real-life contexts, often with unclear boundaries between the phenomenon and its context. It employs multiple sources of evidence (Yin, 1984). Schramm emphasises that the core of a case study is shedding light on decisions, their implementation, and outcomes (Schramm, 1971). The choice of the case study arises from these underlying factors:

- The need to address education and training gaps through 4.0 technologies.
- Evolving engineering methods shaping skills for the 4.0 era.
- Investigating barriers to transformational technology adoption in developing nations.

3.4.5.1 Time Horizon

Time horizons in future studies usually refer to periods to be studied or chronological horizons of varying breadth. Following Kosow and Gaßner's (2011) distinction of the time horizons, which put time horizons into three basic categories, that is,

- short-term – up to 10 years;
- medium-term – up to 25 years;
- long-term – more than 25 years.

This study was clearly in the category of short-term.

3.4.6 Techniques and Procedures

3.4.6.1 Data Collection

A total of 12 qualitative questionnaires were administered; the qualitative questionnaires were then followed by in-depth discussions with respondents to probe into the answers given by the respondents on the qualitative questionnaire. This allowed time for the researcher to process the responses and to further research the answers given so that a more meaningful probing could happen. Advantages of further researching responses and probing:

- Secured first level of data analysis.
- Built preliminary themes.
- Built a precursor narrative that was further confirmed through detail probing.
- Allowed interpretation to be based on a series of iterations rather than simple cause and effect.

The chosen data collection methods were interviews that were semi-structured with open-ended questions, aiming to capture respondent opinions comprehensively.The requests to partipate were done telephonically during the period of May 2023, then followed by a detailed email request to the candidate respondents. The next steps after receiving confirmation to agree to participate was to schedule telephonic interviews which were followed by a final further probing interview.

Qualitative methods provided a deeper understanding of respondents' experiences, unlike quantitative methods. The research explored decision-making processes, considering factors from personal preferences to practical considerations. Qualitative research illuminated the impact of interventions on technology adoption, using a holistic approach that allowed themes to emerge naturally. The study's diversity and holistic approach generated valuable insights into the complex issue, making it a significant contribution.

3.4.6.2 Data Analysis

The responses given by the respondents, observational notes from the indepth interviews and those obtained from further probing were transcribed manually into written form. After the responses were transcribed into written form, common themes were grouped to identify patterns in terms of strategy,(What) processes, functions,(How) politics, (Why) of robotics technology adoption, .The response patterns that resulted from the skills requirements discussions designed answers and solutions to the the concern with the skill challenges. Assigning codes manually was used to assist the process of defining patterns in terms of the concerns with the what,how and why of the responses. Once the data was captured, the researcher used a variety of analysis techniques available for use in the study, inclusive of content, narrative, discourse, and thematic analysis.

To comprehend the data's essence, the analyst engaged in gathering, structuring, and interpreting each datum. Qualitative data analysis differs from the quantitative analysis: qualitative data encompasses words, observations, images, and symbols, making absolute meaning extraction challenging. Hence, it primarily served exploratory analysis. Unlike the clear separation of data preparation and analysis in quantitative research, qualitative analysis often begins upon data availability. Data analysis encompassed reviewing and interpreting collected data. Various techniques were employed and selected based on research objectives and data type. Approaches included:

3.4.6.3 Content Analysis

This popular qualitative data analysis approach encompasses various techniques, including content analysis. Thematic analysis, a subset of content analysis, identifies patterns by grouping text content into words, concepts, and themes. This process quantified the relationships within the grouped content, aiding the researcher.

3.4.6.4 Narrative Analysis

Narrative analysis attempts to comprehend the stories people tell and the language they use to understand these stories. It is particularly useful for gaining an in-depth understanding of respondents' perspectives on a specific topic. A narrative analysis enabled the author to summarise the results of a focused case study.

3.4.6.5 Discourse Analysis

Discourse analysis is used to gain a thorough understanding of the political, cultural and power dynamics that exist in Anglo Platinum's specific situational environment of Anglo Platinum environment. The focus here was on the way people express themselves in different social contexts and to observe the differences between the company employee strata of companies and the commonalities and similarities in each stratum.

3.4.6.6 Thematic Analysis

Thematic analysis, the final approach, centres on respondents' discourse, uncovering the meaning behind their words. By identifying recurring themes in the text, this method provides vital insights and quantification, particularly when paired with sentiment analysis. Sentiment analysis gauges opinions and impressions on various topics. For this study, respondents' views on technology adoption were scrutinised. The analysis produced a code framework representing themes, also called categories. These categories were pivotal in crafting a narrative rooted in the subjects' insights.

3.4.6.7 Interpretation

Qualitative data analysis can be summed up in one word – categorical. With qualitative analysis, data is described through the use of descriptive context. This is the text that is finally presented after it has been coded and categorised. A report was then drawn to represent the findings and to explain how the findings related to the research question.

3.5 TECHNIQUES AND PROCEDURES

The techniques and procedures that were used for data collection and analysis were those supportive of a qualitative research study. During the in-depth probing, the researcher took observational notes. The notes were used as a basis for building preliminary themes that were later used during analysis. Since most of the respondents did not give consent to being recorded, the observational notes were used to derive content and narrative on how critical systems thinking was and could be used in building the robotics adoption strategy. Most importantly, the observational notes and further probing were used to build a narrative on three key themes:

1. Technical (how): Process, structure, functions, collaborations with training institutions, variation of robotics technology usage.
2. Social (what): Vision, goals and objectives; stakeholders needs to give the reality of aligning the project to the company's burning ambition, community needs, suppliers, and various aspects contributing to social licence to operate.
3. Political (why) complex problem situations in organisations. Alignment to shared value, Sustainable development.

The final report of the findings was presented as envisaged in a descriptive context in order to provide insights into the complex issue of adopting robotics technology. The questionnaire had structured questions but was open-ended; this allowed the respondents to describe issues in their own words and made it possible to obtain a comprehensive understanding of the issues. Telephone discussions were also used outside the formal interview where the researcher needed further clarification.

3.5.1 Assumptions, Limitations, and Delimitations

3.5.1.1 Assumptions

The four philosophical assumptions that form the framework for understanding qualitative research are ontological, epistemological, axiological, and methodological. In this study, only two of these assumptions are relevant and important.

The first were ontological assumptions about the nature of reality. This reality was about the survival of the Anglo American Platinum Schools project until the end of the study and that the required respondents were adequately available to the researcher for personal contact. The second assumption was axiological, meaning what is important and valuable in research. These assumptions are based on the role played by social values and on prejudices that define the narrative and interpretation of phenomena.

This assumption considered the respondent's goals, values, mission statements, goals, beliefs, and opinions, as well as the researcher's interpretations. A misalignment between the two could skew the study's results and make them fallacious. Kulinska (2016) opines that axiological research assumes that prejudice influences not only the behaviour and actions of the subject but also the observation and understanding of the researcher (Kulinska, 2016).

3.5.1.2 Limitations

3.5.1.2.1 Lack of previous research studies on the topic

Given that the focus on emerging technologies is a fairly new discipline, limited existing research poses a challenge. Research typically relies on previous studies for theoretical support guiding research questions. However, the scarcity of relevant literature restricts the researcher's ability to draw comparisons and extrapolate ideas. In the absence of previous research, the study ventured into uncharted territory, establishing a unique research typology. Despite limitations hindering comprehensive answers, they exposed gaps in the literature, underscoring the need for future research in this field.

3.5.1.2.2 Time constraints

Similar to deadlines in various domains, academic researchers face time constraints to submit completed reports within study timelines. These practical limitations restrict the time for examining research problems and observing temporal changes. Acknowledging these constraints, the researcher highlights the necessity for future studies to address the research problem and other potential inquiries that this study may not have uncovered.

3.5.1.2.3 The difficulty of investigating causality

Qualitative research requires careful planning to ensure that the results obtained are accurate. There is no way to analyse qualitative data mathematically or statistically. This type of research is based on opinion and judgement rather than results. Because all qualitative studies are unique, it is difficult to replicate them.

3.5.1.2.4 Delimitations

This study focuses solely on issues tied to the adoption and responsible implementation of specific systems within the Anglo Platinum School Project. It does not address similar concerns within other companies or problems arising from the adoption of different systems within Anglo American Platinum Schools Project. The study's scope is limited to Anglo Platinum School Project staff members and partner instiutions. Exclusions include:

- Contractors,
- Vendors of AAP School Project.
- Union representatives
- Employees of the company outside the AAP Schools project

3.6 CONCLUSION

The integrated early talent strategy defined by AAPSP is based on the understanding that the adoption of robotics technology in the mining sector, including AAP, is being used to automate various tasks to improve efficiency, safety, and productivity. The AAPSP frame of reference and departure point deriving the integrated early talent strategy is that the drivers behind the adoption of robotics technology include but are not limited to the following:

- Rising liabilities,
- Increasing environmental sustainability compliance costs,
- Compliance with safety regulations,
- Lower grades of mining produce.

Key areas of application of robotics technology (variation of use) include:

- autonomous haul trucks and drilling systems,
- remote-controlled mining equipment,
- inspection robots,
- automated mineral sorting, and
- automated mine rescue.
- Wearable mining technology and exoskeletons are future areas of development in robotics technology.

Though mining can benefit from automation, a comprehensive approach integrating human and social aspects is crucial for people-centric robotics adoption, ensuring relevance and accountability. Clear understanding before adoption is vital to avoid wasted resources and employee resistance. Implementing robotics demands specialised technical, problem-solving, collaboration, and digital literacy skills. Developing these, including systems thinking due to the importance of having to solve for relevancy, fit for purpose , diversity and conflicting value systems of stakeholders to maximises robotics adoption benefits.and related skill development.

This research focused on the AAP School Project, aiming to address robotics adoption and skill challenges. Employing the research onion framework, it took an interpretivist stance, valuing qualitative insights. Using inductive qualitative methods, it gathered insights from interviews, observations, and focus groups.

The case study method was chosen due to its ability to explore contemporary phenomena in real-life contexts.

- The shortfall of education and training systems in providing a curriculum that can help relevancy, applicability, and accountability in technology adoption.
- The evolution of engineering and technical methods redefining the skills required in the 4.0 era.
- The importance of planning future strategic workforce planning as part of early talent development g.
- The need for visionary leadership and thinking in planning for the transformational utilisation of 4.0 technologies in the context of developing countries.

The researcher used various methods, including in-depth interviews, telephonic-based further probing, texts and documents, and observational notes. The researcher chose these methods based on the research onion step-by-step process, which led to the selection of data collection and analysis procedures that could answer the research and investigative questions.

Overall, the research approach used in this study was designed to provide a comprehensive understanding of the issue at hand by incorporating a range of data collection and analysis methods while emphasising the importance of context and understanding people’s beliefs and motives. By following the research onion framework, the researcher was able to approach the study in a systematic and structured way, ensuring that the research objectives were met and the findings were robust and reliable.

CHAPTER 4 –
DATA PRESENTATION, INTERPRETATION, ANALYSIS AND DISCUSSION

4.1 INTRODUCTION

This chapter details the findings of the study after the data was collected and analysed from the qualitative research questionnaires administered with early talent managers, school project managers and Anglo American Platinum School Project (AAPSP) partner higher education professionals. The analyses of the data collected aimed to comprehend how the use of critical systems thinking (CST) can benefit AAPSP's early talent development strategy.

The key outcome of the analysis was to primarily determine how CST can enhance the capability of the AAPSP to co-create robotics technology adoption strategy and skills that are competent to solve for responsible mining. The outcome of the analysis was also formed the basis to recommend how the AAPSP can use CST to achieve a holistic early talent development strategy for robotics technology adoption which solves for contributing to value creation and responsible mining. The outcomes of the research analysis confirm the findings of the literature review that an incomplete or misguided perspective on the problem context when adopting robotics technology compromises the impact that robotics technology has on responsible mining.

The AAPSP seeks to align the development of robotics technology skills with the creation of shared value, responsible mining, environmental, social and governance (ESG) goals, social labour plans, and transformation commitments. A key component of the AAPSP's strategy for integrated early talent development is delivery of localisation of technical skills. The analysis focused primarily on how CST can be applied in the context of the AAPSP as a problem-solving technique to identify ways of alleviating hindrances to the utilisation of robotics technology and hence benefit the achievement of localisation of technical skills.

The analyses of the data focused on understanding the extent to which CST methodology is being utilised to investigate the challenges of robotics technology adoption and used in the co-creation of the skill relevant to solve for localisation of technical skills, which are inclusive of localisation of skills to achieve robotics technology adoption.

The three phases of local systems intervention within CST as outlined in the literature review were used as a basis for investigating the people oriented robotics technology problem situation:

1. Creativity: Innovative thinking about challenges in adopting and implementing robotics technology.
2. Choice: Selection of suitable methods to address these challenges.
3. Implementation: Application of chosen methods.

4.2 ANALYSIS OF THE FINDINGS

The current AAPSP understands and concerns about robotics technology adoption are mostly oriented towards a hard systems approach encompassing design, maturity of the robotics technology and technology readiness. The approach emphasises process, design, and structure, aligning with traditional principles like advantage, compatibility, complexity, trialability, and observability. Procurement-related factors such as market position, maintenance, work functions, and organisational support also play a key role in the current early talent strategy development. At this dimension of strategising, unpacking assumptions behind robotics technology utilisation reveals purpose-driven benefits such as safety improvement, production rate increase, deeper mining capabilities, labour solutions, workforce reduction, and cost savings.

While functionalist considerations are crucial for productivity and safety, a sole focus on instrumental goals overlooks emergent opportunities like shared value creation and responsible mining. The concern with “What” in robotics technology adoption would involve taking cognisant of diverse stakeholder perspectives on the goals of robotics technology adoption and resultant AAPSP early talent strategy goals and objectives. CST asserts that an organisation is shaped by varied viewpoints, highlighting the insufficiency of a purely functionalist rationale in crafting a robotics technology development strategy. Designing the robotics technology adoption strategy and the resultant early talent development approach must factor in power dynamics and ideologies fostering robotics technology and its adoption. Most importantly, this dimension of thinking would need to include the diversity of stakeholders to deliberate and determine options (goals and objectives).

A concern with the "Why" dimension involves exploring reasons behind the different robotics technology adoption goals and objectives as held by a diversity of stakeholder groups. This dimension of thinking enhances the capability to address possible conflicting values of different stakeholders (inclusivity of viewpoints, e.g. labour, staff, and affected communities). Unpacking these motives reveals beneficiaries, (empowerment issues) ethics and socio-economic advancements. Solely adopting a hard, functionalist view neglects social dimensions, raising questions about sustainability and responsible mining.

On the whole, the outcome of the data analysis indicates that the AAPSP's early talent strategy development leans towards a positivist-functionalist approach driven by industry influence, technology maturity, design, practical purposes, and market trends. However, this overlooks a holistic perspective that should encompass not just design and practical use but also politics, organisational impacts, and societal changes from robotics implementation.

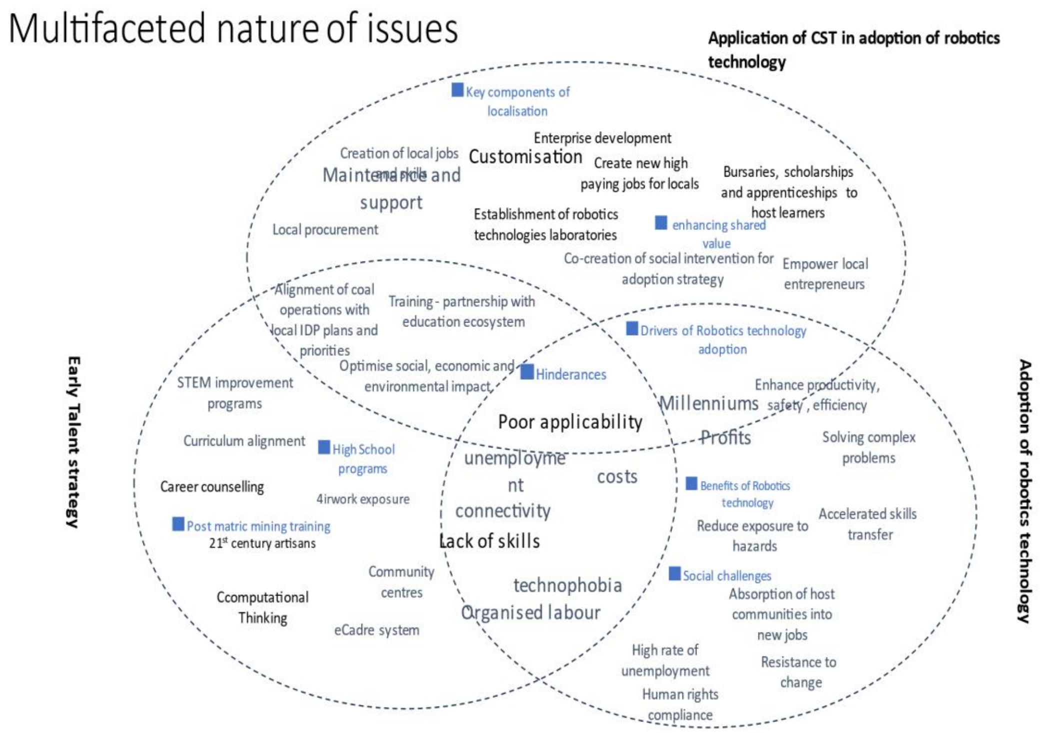

Figure 3-3: Multifaceted nature of robotics adoption issues

4.2.1 The Drivers for the Uptake of Robotics Technology?

A combination of technological advancements, the need for increased productivity and efficiency, the development of relevant skills, and the mining industry's need for safety, efficiency, and cost reduction are driving the adoption of robotics technology. These are the factors collectively but primarily contributing to the design of robotics adoption and early talent strategy development of the AAPSP.

4.2.2 Perceived Benefits of Robotics Technology?

The view driving the adoption of robotics technology strategy for the AAPS is primarily driven by safety concerns, productivity and efficiency improvements, risk reduction, and less by the potential for social benefits such as job creation and skills development.

4.2.3 Disadvantages of Utilising Robotics Technology?

The responses highlight robotics' benefits as being mainly safety and productivity but express major worries about its negative social and economic impacts of job loss, higher unemployment, skill mismatches, and financial burdens in mining. The overall feeling from the participants is that AAP has an opportunity to address these downsides by focusing on strategic workforce skilling through AAPSP early talent development. Respondents emphasised the poor applicability of robotics as a hindrance to adoption.

4.2.4 How to Apply Critical Systems Thinking in the Adoption of Robotics Technology

Perceived components of a holistic strategy in adopting robotics technology?

There is a general perception from the respondents that a holistic strategy for adopting robotics technology in the context of the AAPSP will involve a multifaceted approach that encompasses not only technical aspects but also cultural, educational, and workforce development considerations. This comprehensive approach is essential for successful and sustainable technology integration.

4.2.5 Key Principles of a People-centric Robotics Adoption Strategy?

A recurring theme in the participant's understanding of people-centric robotics adoption strategy places a strong emphasis on awareness, education, clear communication, collaboration, and workforce development. Generally, respondents centralise the benefits both to the organisation and its employees, emphasising the importance of human skills and roles in conjunction with automation and robotics technology. The overarching response is that achieving a people-centric strategy is critical, and AAPSP should deploy strategies that allow comprehension, planning and skills delivery for a people-centric robotics technology adoption.

4.2.5 How Can Anglo American Platinum School Project Achieve Such a People-centric Strategy?

Importance of a concerted effort to educate, engage, and empower the workforce, and host community. It involves a collaborative and transparent approach that values employee and local host communities and relevant stakeholders' input and invests in their development to ensure a successful transition to a strategy that prioritises both people and technology.

4.2.6 Social Challenges Faced When Implementing Robotics Technology

The predominant response is that the social challenges related to robotics technology implementation revolve around potential job losses, economic inequalities, community resistance to change, and the need for both institutional and community inclusivity and well-being considerations. These challenges highlight the importance of comprehensive planning and strategies to mitigate negative social impacts while reaping the benefits of technological advancement.

4.2.7 Creation of a Shared Value With Host Communities Advancement of Socio-economic Conditions of the Communities Through the Adoption of Robotics Technology?

When asked how the adoption of robotics technology can be aligned with the creation of value for the AAP business, respondents highlighted the importance of a multifaceted approach that focuses on skills development, education, local entrepreneurship, infrastructure development, and collaboration. These strategies aim to ensure that the adoption of robotics technology contributes to the socio-economic advancement and well-being of the communities in which they operate.

"

When commenting on the future of Robotics technology :

"It is a critical technology improving productivity and efficiency"

"This is the way to go, the positive impact will have ripple effects as it will improve the economy and result in new jobs"

Ït will free up workers for other roles that will require more skills

"Robots do not get tired so productivity of processes would increase dramatically"

"Robots can be trained for precision and so high precision activites become more doable more often

4.2.8 Key Components of Localisation of Robotics Technology?

The overarching trend is that the localisation of robotics technology involves a multifaceted approach that focuses on education, skills development, entrepreneurship, preferential procurement, infrastructure, and government collaboration. These strategies aim to ensure that the benefits of robotics technology are shared with and accessible to the local communities, contributing to their socio-economic advancement and well-being.

4.2.9 The Impact of Robotics Technology on Sustainable Development?

Overall, respondents argued that robotics technology has a multifaceted impact on sustainable development, encompassing aspects related to safety, productivity, education, environment, innovation, and economic growth. It plays a crucial role in addressing various global challenges and contributing to a more sustainable future.

4.2.10 How Does Robotics Technology Affect Sustainable Development?

The overarching view is that the impact of robotics technology on sustainable development is complex, with both positive and negative aspects. While it can improve safety, productivity, and environmental practices, there are concerns about economic disparities and high upfront costs. The extent to which robotics technology contributes to sustainability in mining depends on various factors, including how it is implemented and managed.

4.2.11 Skills and Skills Development

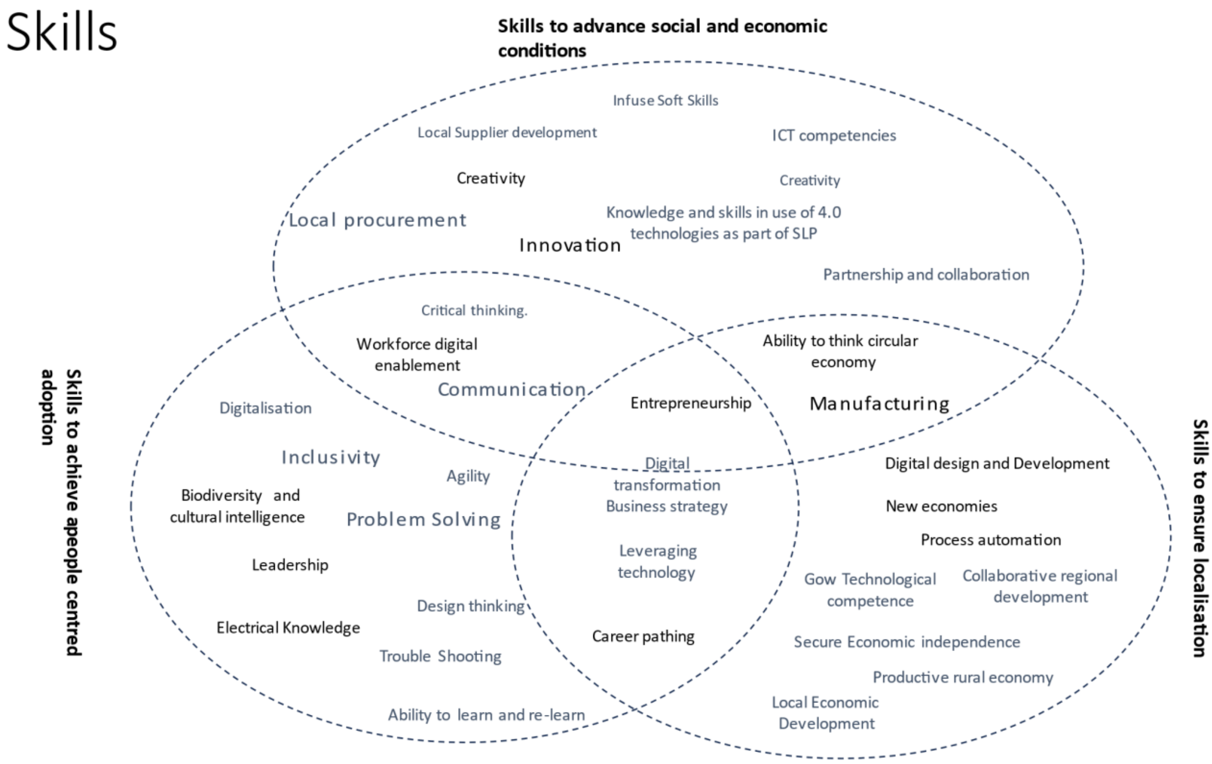

Figure 4-4: Skill challenges

The role of digital transformation policy development that centralises early talent strategy was indicated as a key pillar for achieving a people-centred skills development strategy. In addition, respondents also highlighted the significance of an integrated approach to skills development from basic education sources through high school robotics-coding infusing programmes and specialisation of robotics technologies curriculum at the tertiary level. The role of community development programmes in partnership with sector-based institutions to achieve localisation of skills is important. On the whole, CST has been highlighted as a key skill that can enhance people-centric and responsible adoption of robotics technology.

4.2.12 Skill Challenges Of Using Critical Systems Thinking Approach to Robotics Technology

When asked to rate the relevancy of soft skills in the adoption of robotics technology, the following landscape came out:1: Irrelevant, 2: Partially relevant, 3: Critical.

Table 4-2: Skill Challenges of Using Critical Systems Thinking

Creativity: ability to generate, recognise new ideas, to do things, and to solve problems	Rated as critical by all the respondents
Emotional intelligence: ability to express and be cognisant of others' emotions. Empathy, integrity, and ability to work well with others.	Rated as critical by the following respondents: Resp04 Resp05 Resp07 Resp12
Critical Thinking Skills: ideal in human-machine relationships and collaboration for improved productivity.	Rated as critical by all the respondents
Active learner mindset: Capabilities to actively learn and grow. Willing to take on new challenges, learn from mistakes and actively seek new knowledge.	Rated as critical by all the respondents
Judgement and decision-making: Human decision-making will become more complex as machine-driven information processing will continue to evolve and be complex.	Rated as critical by all the respondents
Interpersonal communications: communicate and exchange information and meaning between people.	Interpersonal communications was rated as critical by the following respondents Resp01

	Resp04 Resp06 Resp07 Resp08 Rep09 Resp10 Resp11 Res12
Leadership: ability to inspire, help and motivate. Identify talent and do better for the good of the bigger picture	The following respondents rated leadership as critical : Resp01 Resp02 Resp03 Resp04 Resp06 Resp07 Resp08 Resp11
Diversity and cultural intelligence: ability to understand, respect and work with others who have a different way of seeing things.	Rated as critical by all the respondents
Embrace change: the ability to be agile, embrace and celebrate change.	Rated as critical by all the respondents

Interestingly, all the soft skills were rated by all of the respondents as critical, except for emotional intelligence and interpersonal communications.

4.2.13 Change Management

In analysing the status of the current change management in skilling for the strategic workforce, the following picture came out where 1: Some discussions have taken place, 2: Strategy and action plan in place, 3: Good and sustained progress is taking place, 4: statement is definitely true.

Table 4-3: Change Management Issues

Statement	**Percentage of respondents**
Universities and other training institutions have the necessary training and development programmes to support the effective and efficient implementation of robotics technology	The following respondents indicated that good progress is taking place by educational institutions to offer training and development programmes to support effective and efficient implementation of robotics technology: Resp03 Resp05 Resp07 Resp08 Resp11 Resp12
Post Post-matric career transitioning equips learners with a good understanding of robotics technology and its benefits in the mining sector	Most of the respondents indicated that there is limited activities happening in fusing robotics adoption technology skills at source of education ecosystems
Robotics technology is bringing about career opportunities in the mining sector	Majority of the respondents indicated that robotics technology is bringing about diversity in employment opportunities
There is a clear strategy in curriculum development that solves for relevancy in the use of robotics technology	Majority of the respondents believe that there is no strategy in ensuring curriculum development that address shortage of skills that can solve for a people centred robotics technology adoption
Current curriculum development and training initiatives have a clear strategy in place to align skill development and implementation of robotics technology with transformation, ESG goals and mining charter requirements	All the respondents believe that skill development in the discipline of adoption of robotics not aligned with goals the national goals of development, ESG and transformation of the mining sector
There is a clear strategy, vision and roadmap for future robotics skills requirements	Only Resp12 indicated that there is a vision and roadmap for future skills requirements related to robotics technology
There is a strategy in place to guide early talent roadmap for closing current and future robotics skill gaps	Only Resp10 and Resp12 indicated that there is strategy for closing gaps in robotics skill requirements

There are clear processes and structures that align host community development skills with current and future robotics technology skills of the company	Only Resp11 believe that the adoption of robotics technology will positively increase creation of shared value with local host communities
Host communities' digital divide increases due to robotics technology utilisation by the mine	All the respondents indicated that the adoption of robotics technology increases the digital divide in the host communities
Opportunities for the host community's empowerment programmes aligned to robotics technology are identified	All the respondents indicated that there is minimal effort being undertaken to identify programs that can empower communities to be players in the digital transformation

In summary the analysis indicates that respondents believe that the adoption of robotics technology is not being implemented in a holistic manner. The digital divide is seen to be growing as a result of a lack of people-centric-led digital transformation goals.

4.3 OBJECTIVE CREATIVITY: HARD ONTOLOGY AND A REALIST EPISTEMOLOGY (HOW)

The core issues compromising the responsible mining goals due to robotics technology adoption's relevance relate to the disregard of fundamental cybernetics laws. These issues include:

1. The school project's adoption strategy lacks alignment with the local environment's needs for responsible mining and sustainability goals. Challenges encompass local community advancement, youth unemployment, the absence of local robotics technology suppliers, and dependence on overseas research and development of robotics technology's by mining operations.
2. Internal processes of the school's project do not position the delivery of a robotics skills development strategy that adheres to both national and mining sector's policies and regulatory frameworks governing inclusive transformation. This misalignment affects the delivery of early talent strategy that is aligned with national development goals, education curriculum, and transformation goals.

The current strategy is misaligned with the government's 4IR policy and internal ESG , therefore posing persistent challenges in the integrated early talent strategy that solves for relevancy , fitness of robotics technology purpose given existing conflicting stakeholder values . A lack of alignment of skill localisation with overarching developmental goals, results in a future talent pool misalignment with responsible mining objectives. Mere ESG policy presence is not enough; it must guide responsible robotics adoption, a key missing aspect impacting early talent strategy in the school's project.

4.4 SUBJECTIVELY SPEAKING, SOFT ONTOLOGY, INTERPRETIVE EPISTEMOLOGY, AND A CONCERN WITH (WHAT)

Robotic technology impacts various stakeholders. Stakeholders include:

- Workforce affected by robotics technology adoption.
- Local communities expect benefits like increased productivity and socio-economic advancement.
- Regulatory bodies, e.g. Department of Labour, Department of Minerals, Minerals Council, and mine management, hold decision-making power.
- Professional consultants representing OEMs and the mine, handling project management, HR, and strategic workforce planning.
- Other interested parties are not directly affected by the project, such as witnesses.
- Stakeholder composition and influence evolve based on the project's phase.

The AAPSP's robotics technology adoption, from the perspective of the affected workforce and unions, is perceived as a solution addressing the following:

- Health and safety concerns.
- Opportunities for upskilling into more valuable roles.

It is widely believed that robotics adoption enhances safety and productivity while also creating employment opportunities. On the other hand, the technical professional teams, including robotics technology suppliers, aim to achieve optimal results while empowering both the workforce and host communities. Considerations encompass:

- Enabling workforce benefits through early talent development.
- Community involvement and benefits, such as supplier and entrepreneurial opportunities arising from automation and robotics.
- Execution of the project by the professional team in alignment with their expertise.

- The project’s overall impact on company transformation goals and the mining sector.

Defining the vision, mission, and objectives of a people-centred robotics adoption strategy for the school project should involve consultation with diverse stakeholder groups, each motivated by distinct reasons.

4.5 Concern with ‘how’ of design

The robotics adoption guideline needs to prioritise sustainable processes and structures from early planning, ensuring both short and long-term viability within and beyond the organisation. Aligning with critical national strategies like development plans, skills, spatial frameworks, and mining charters is crucial, making the adoption policy comprehensive and responsible. This means the project must carefully design and implement processes and structures that enhance ethical, relevant, and responsible automation, even amid potential internal and external fluctuations.

4.5.1 Concern with “What”

Neglecting ideologies, power dynamics, and pre-existing functions in robotics poses risks. Without critical awareness of imported technology’s political underpinnings, local skills may be underutilised. Implementation must align with national plans, skills regulations, and mining goals to prevent inadequate maintenance and reliance on foreign skills. Diverse stakeholder perceptions stress contextual planning; isolated strategies may undermine relevant and responsible robotics adoption.

4.4.2 Concern with “Why”

Adoption The adoption of robotics technology in a sustainable manner depends on addressing ownership and involvement, considering diverse stakeholder perspectives for relevant and emancipatory skill development. Implementation requires efficient processes and structures to achieve goals of relevancy and emancipation. The responses were further categorised into themes: Strategy, People Capacity, and Business Processes.

4.5 SUMMARY OF IDENTIFIED CORE ISSUES OF CONCERN

1. First world driven ideologies remain the driving force behind the rationale and understanding of robotics technology; this makes the adoption of this technology a mere cut and paste without a proper investigation and research of the social, ethical, legal, societal and other sustainability issues which robotics technology needs to solve. This approach to technology adoption compromises the goals of responsible mining and relevancy.
2. Implementation of the robotics technology is not based on local expertise but is highly reliant on exported skills and knowledge affecting relevancy , fit for purpose and conflicting stakeholders values. This also has negative implications for relevant skills development strategy
3. Lack of community capacity building, training, and guidance by professional technical expertise to bridge the digital divide.
4. Lack of local manufacturing of robotic technology causing low-impact local enterprise development and local procurement
5. Current school project management structures driving the implementation of robotics projects do not have a correct link with the human capital and human capital assets of the host communities.
6. Although robotics is a requirement and a key component of evolving 4IR, modernised and mechanised mining, it does run the risk of becoming detached from serving the empowerment and correct skilling early talent pipeline and host communities (if reskilling happens, it is likely to take place at the most minimum extent by the initiators and implementers of the robotics technologies).

4.6 CHOICE OF INTERVENTION STRATEGY TO ADDRESS CORE ISSUES OF CONCERN REGARDING RESPONSIBLE ADOPTION OF ROBOTICS TECHNOLOGY AND RELATED SKILLS

AAPSP should prioritise cultivating critical thinking skills. This can be done through collaborating with community high schools, the Department of Education, higher learning institutions, and industry experts. The project can establish a blended learning platform. This platform can, amongst other aim to culture creativity, problem-solving, and innovation skills essential for adopting robotics technology effectively:

- Equipping early talent candidates with practical critical thinking skills, including planning, communication, teamwork, and resilience.
- Integrating environmental awareness into holistic education (aligned with responsible mining principles).
- Establishing cross-curricular and trans-disciplinary connections for real-world learning.
- Offering a DBE CAPS-compliant programme for practical robotic technology skills.
- Implementing character and leadership development projects.
- Addressing the scarcity of green and blue economy skills in early talent development.

4.6.1 Delivery Approach

1. “Re-imagining 4IR: Embracing the Present and Future” - The schools’ project acknowledges the presence of 4IR and immerses future workforce (early talent) in its concepts early on, fostering shared value for mining. This includes nurturing soft 4IR skills like creativity, imagination, and problem-solving.
2. “Integrated Early Talent Ecosystem” - The school project integrates a career development curriculum, school programmes, youth leadership initiatives, and sector-based education. This holistic approach avoids isolation and achieves integrated high-performing early talent solutions.
3. “Empowering the Girl Child” - The project focuses on empowering girls for careers in AAP’s future robotics by promoting inclusivity and compliance with transformation goals.
4. “Cultivating Innovation Skills” - Early development of innovation skills is key for responsible robotics adoption. The strategy involves nurturing creativity and innovation from basic education, recognising their importance in addressing mining challenges through robotics technology.

“Partnering for Creativity and Innovation” - Collaborating with technical schools cultivates creativity and innovation, forming the foundation for locally relevant and adaptable robotics technology aligned with socio-economic needs.

“Nurturing Innovation Talent” - AAPSP not only nurtures innovation and creativity skills early on but also offers a pathway to becoming 21st-century robotics technology artisans, ensuring the proper career development of innovation talent.

4.7 DISCUSSION

As one would have expected 90% of the respondents indicated that critical systems thinking and complex problem solving are the key skills that are critical in achieving a successful people oriented technology transition in the mine sector (question 4.1). The direct responses included answers such as :

1. Soft skills,
2. Critical thinking
3. Creativity
4. Innovation
5. Negotiation
6. Problem solving
7. Communication
8. Personal mastery

Most importantly the respondents also indicated that the current education system is not aligned to the skills set provision of critical systems thinking (question 5.2). According to the respondents, basic education and institutes of higher learning are failing in supplying the forecasted demand for critical skills thinking skills that can help the mining industry achieve a people oriented adoption of robotics technology

Respondents identified issues such as :investment in systemic STEM research and skills development “as key principles of a people centric robotics adoption (answer to question 3.2). The importance of an evolved computational thinking training and development strategy was also identified as a key a ingredient of curriculum revitilisation in the education system (question 5.1) This is in line with the finding of the literature where CST thinking aligned computational thinking has been identified as key ingredient for K12 cognitive skills training (Hamidi, Mirijamdotter, & Milrad, 2023).

When asked what they think are the key components of localization of robotics technology , respondents spoke about:

1. “investing in infrastructure including institutions that enable the teaching of these non -existent skills”and for “schooling curriculum to include robotics technology
2. “Implementation of community programs in community centers to focus on CST boot camps”

According to the outcomes of a recent qualitative research (de Holanda, 2024), respondents indicated that “The demand for higher qualifications and high-skilled jobs is rising substantially within the mining industry as mining companies have stronger competition and more complex operating landscapes” . when asked about the skill sets in mining industry due to advanced technology adoption .

Interestingly the same study (de Holanda,2024) confirmed the current literature review findings as unpacked in section 2 that complex problem-solving skills are the skills with the highest demand by the mining and that mines of the future are looking for people who, are lifelong learners, are adaptable to changes and have strong interpersonal skills such as teamwork, communication, and leadership. This is aligned to literature findings in section 2 which defined the CST traits described by Jackson (2010).

4.8 CONCLUSION

The age of AI demands organisational structures that use technology to empower people (Sanders & Wood, 2020). Adopting robotics technology requires a nuanced CST approach, dissecting multifaceted problems for inclusive solutions (Jokonya, 2016). The AAPSP aims to deliver high-performing robotics technology adoption skills in line with becoming a leading mining entity and societal betterment. The envisaged integrated early talent strategy must align with the company’s vision, core values, and socio-economic advancements of impacted host communities.

Intelligent technologies such as robotics reshape employment but raise concerns of job displacement. At a high level, AAP’s robotics adoption demands a cautious approach to prevent unemployment and adverse local economic effects (Minerals Council, 2015), and the CST framework will benefit AAPSP in this regard by facilitating processes, structures and strategies for AAPSP to align with a creative problem-solving technique that will land a responsible adoption of robotics technology (Flood, 1996; Mingers & White, 2010).

Skills for responsible robotics technology use align with the company's shared values and overarching goals. These skills go beyond the current education curriculum and address technology impediments such as aligning with AAP's ambitions, responsible mining, and transformative objectives.

Incongruence undermines technology's transformative potential in mining. AAPSP vision of solving for relevant development tof skills in robotics technology adoption should prioritise CST skills to ensure relevance and responsible implementation, going beyond design goals to catalyse broader institutional and societal transformations. The research confirms the literature review findings that misconceptions or limited perspectives on robotics adoption hinder its positive impact on responsible mining.

CHAPTER 5 – CONCLUSION

5.1 INTRODUCTION

The South African mining sector plays a vital role in the country's economy due to its rich mineral resources. Past socio-political dynamics favoured mining operations and enabled its success. However, today's mining industry faces contemporary challenges such as market-related wages, unstable commodity prices, unionised labour, and environmental concerns, therefore adding to the socio-political pressure faced by today's mining sector.

In addition, the dawning 4.0 revolution is exerting technological and skill challenges that the mining industry has to deal with. In order to thrive, SA mining companies need to embrace available technologies. Yet, the lack of a formal implementation strategy for mechanisation and digitalisation might strain labour relations. Failure to adopt 4.0 technologies risks will put SA mining house's global competitiveness at risk due to higher labour costs compared to international mining houses, which will be able to mine effectively and efficiently due to the utilisation of 4.0 technologies such as robotics technology.

In light of the above, the current socio-political challenges faced by SA mining houses, which unfortunately are unique to the South African reality, are not making it easy for the mining sector to adopt the technologies without the possibility of impacting negatively on the transformation and environmental, social and governance (ESG) identity of the mines. Mines, therefore, need to find ways to adopt technologies in a responsible and relevant manner, given the context of South Africa's developing economy and its developmental state.

While 4.0 technologies promise cost reduction and operational growth, their implications in mining differ from sectors like manufacturing or banking. Adoption will impact workforces, mining communities, procurement, and institutions and also reshape societal dynamics. This is because the advancement of technologies such as robotics, AI, and big data will transform the SA mining landscape, potentially leading to job displacement (Bryanstjolfsson & Mcafee, 2010).

This research concludes that, in order to redress this possible negative trajectory, a responsible, people-centred robotics adoption strategy in mining should be embraced. Critical Systems Thinking (CST), specifically local systems intervention, is recommended. Conventional technology adoption approaches lack interpretive, emancipatory, and postmodern perspectives, limiting responsible mining strategies.

The mining sector needs skills beyond technology application. These skills have been identified as a first line of defence when adopting robotics technology and imply competency in critical systems thinking and local system intervention because they are skills that solve for relevancy, fit for purpose and address any conflicting values.

5.2 OVERALL CHALLENGES IN ADOPTING ROBOTICS TECHNOLOGY

In referencing the outcome of scholarly articles on the different challenges faced by SA mining houses when implementing digital transformation, Zulu et al. (2021) summarise that challenges that mining companies face when implementing digital transformation include operationalisation of a business strategy (linking objectives with information data), change management, effective application of technologies and managing external constraints.

Several fundamental issues need to be considered to ensure that the technology is introduced, not simply because it is available (Dempsey et al., 2018). The introduction of technology requires careful consideration of its relevance and applicability rather than its mere availability. Key issues include early ergonomics integration, participatory research, human-centred design, societal factors integration, and responsible adoption strategies.

Challenges in adopting mining robotics in SA include premature application, culture mismatch, and societal concerns. Stakeholders’ readiness for autonomous mining and engineering programme shortcomings are identified. A skilled labour force is crucial for a digitised mine. Automation in mining lags due to adverse environments and low investment incentives. Telerobotic and mine-wide robotic mining roles are uncertain, but embracing tech enhances operational excellence. Despite obstacles, mining firms invest in robotics for efficiency and safety gains.

5.3 IMPLICATIONS FOR SKILLS

The unitary approach underscores the need to adopt technology as a direct response to solving specific problems and updating relevant skills. Unfortunately, robotics adoption often occurs due to trends or competitive pressures, neglecting the importance of understanding the problems it should solve. Mining companies should thoroughly understand the issues they face and how robotics can address them. Involving stakeholders helps identify pain points and assess if robotics technology is the right solution. Thoughtful adoption aligns robotics with responsible mining, ensuring a shared value that earns social acceptance. Mining needs skills in identifying, operating, and sustaining robotics for socio-economic development (Khubana, 2022; McKinsey, 2019; Ralston et al., 2017).

Building human capital in robotics deployment, application, and utilisation will optimise the performance of a robotics technology-driven digital transformation strategy. This will benefit the mining company’s shared value and sustainable development. Reskilling workers and management amid South Africa’s expanding technical education system is also a crucial part of a robotics technology-enhanced digital transformation plan. Mining personnel need skills in managing capital-intensive robotic equipment (Vogt, 2014) to address relevancy, conflicting values, and fit for purpose aspects, crucial for responsible mining strategies.

In SA digitalisation of mines is anticipated to create jobs but also displace many by 2030, potentially weakening trade unions and the ANC government. The role of organised labour in the technology transitioning of the mining industry remains critical, as unions power’s are likely to be eroded by the loss of members (as the human workforce gets displaced by robotics and automation functions). Tensions persist among mining companies, government, workers, and communities regarding job creation, wages, conditions, and environmental protection. Political resistance may hinder technology adoption (Acemoglu & Robinson, 2019). The mining industry’s political settlement changes incrementally due to technological disruptions rather than sudden shifts.

5.4 CONCLUDING REMARKS ON THE CASE STUDY

The overall findings of the literature review and case study endorse a CST approach to robotics technology adoption, suggesting that when addressing concerns of emancipation, empowerment, emotion, pluralism, efficiency, and efficacy, a nuanced perspective is essential. Instead of a simplistic cause and effect approach, the problem's multifaceted nature should be dissected through diverse perspectives, leading to inclusive solutions (Jokonya, 2016).

The Anglo American School Project (AAPSP), in its endeavour to provide a foundation for integrated early talent strategy, aims to co-create high-performing robotics skills that must align with the company's ambitious goal of becoming the world's most valued mining entity by 2030. This objective intersects with the company's overarching purpose of re-imagining mining for societal betterment. Therefore, the robotics technology strategy within the school project should seamlessly integrate with this overarching vision. Furthermore, the strategy should conform to the company's core values, emphasising the advancement of socio-economic conditions within impacted communities to secure sustainability and social licence to operate.

Contemporary literature recognises the transformative potential of robotics and other intelligent technologies, such as artificial intelligence, machine learning, big data analytics, smart sensors, and the Internet of Things, in reshaping employment landscapes. These technologies herald an era of industrial transformation, raising concerns about widespread job displacement.

The adoption of robotics technology by AAP Mine necessitates a judicious approach that avoids adverse consequences such as rampant unemployment and detrimental economic effects on local communities (Minerals Council, 2015). CST intervention offers a system-based problem-solving technique that facilitates relevant and responsible robotics technology adoption. This approach enables creative problem identification, informed choice-making, and effective implementation of locally relevant solutions (Flood, 1996; Mingers & White, 2010).

The quest for skills that enhance the responsible utilisation of robotics technology is best aligned with the company's shared value system, encompassing its purpose, ambition, and responsible mining objectives. These skills are not solely rooted in the design and application variability of robotics technology; rather, they stem from the profound shared value embedded within Anglo American Platinum's (AAP) ethos.

The skills challenge transcends mere education system constraints and the replacement of scarce skills with technology; it extends to addressing the impediments to technology utilisation. As expounded earlier and supported by the literature review, these obstacles arise from shortcomings in reconciling utilisation patterns with on-ground realities. Specifically, the alignment of robotics technology with the company's overarching ambitions, purpose, responsible mining plan, and transformative goals embodied in social labour plans, ESG commitments, and mining charter objectives.

A pivotal impediment to technology utilisation is the incongruence and lack of suitability that undermines transformational goals in the mining sector (Lind, 1991; Takawira, 2019; Makhene & Thwala, 2009). Consequently, AAP's adoption of robotics technology should prioritise skills steeped in CST to address relevance and responsible implementation. This implies that robotics technology implementation should transcend the mere pursuit of design goals and applications. Instead, it should holistically address broader objectives of contributing positively to institutional and societal transformations catalysed by AAP's mining endeavours.

5.5 RECOMMENDATIONS: APPLYING LOCAL SYSTEMS INTERVENTION AS A FRAMEWORK TO BUILD THE FOUNDATION OF ADOPTING ROBOTICS TECHNOLOGY

The South African mining landscape faces challenges with digital transformation impacting employment. Slow digitalisation due to geological complexity and costs contrasts with the rising investments in digital initiatives by mining companies (Ndlovu, Ngwane & Mongae, 2022). Scientifically predicting the effects of this transformation remains uncertain, varying from displacement to reinstatement. Most of all, it is worth noting that the trajectory of South African mining's digital shift differs from developed nations or the banking sector's journeys.

The impact reinforces or accelerates adoption, contingent on who benefits from the political settlement (organised labour, mining leaders, communities, government) and the technology’s ability to address relevancy, purpose, and conflicting values for a people-oriented digital transformation.

CST affords this complexity with an evolved management science-based problem-solving technique that transcends disciplinary boundaries and practice to benefit the sector in solving such complexity. It recognises the strengths and weaknesses of different approaches (Jackson, 2010). It addresses complex societal situations, incorporating pluralism and improvement into problem-solving models.

Developing high-performing talent for robotics adoption at Anglo American Platinum requires the application of such a technique capable of solving complex problems beyond simple cause-effect theories (Zulu et al., 2021). CST is crucial in the context of a complex-laden robotics technology adoption strategy addressing emancipation, diversity, and empowerment challenges that accompany the process of robotics technology adoption.

It is vital to identify and address relevant problems related to robotics adoption through the local systems intervention (LSI) model. LSI involves creative thinking, choice-making, and implementation phases to align technology values with responsible mining and societal needs.

The lack of skills that are required to achieve precision in problem identification and solution conceptualisation impedes robotics technology adoption’s alignment with responsible mining. CST aids in solving relevancy, fit for purpose and conflicting values and therefore, skills development strategy for robotics technology adoption should foster competency in solving for relevancy, fit for purpose and fostering talent for people-centric robotics adoption.

Mining’s evolving landscape requires new skill sets not yet addressed by existing education systems.

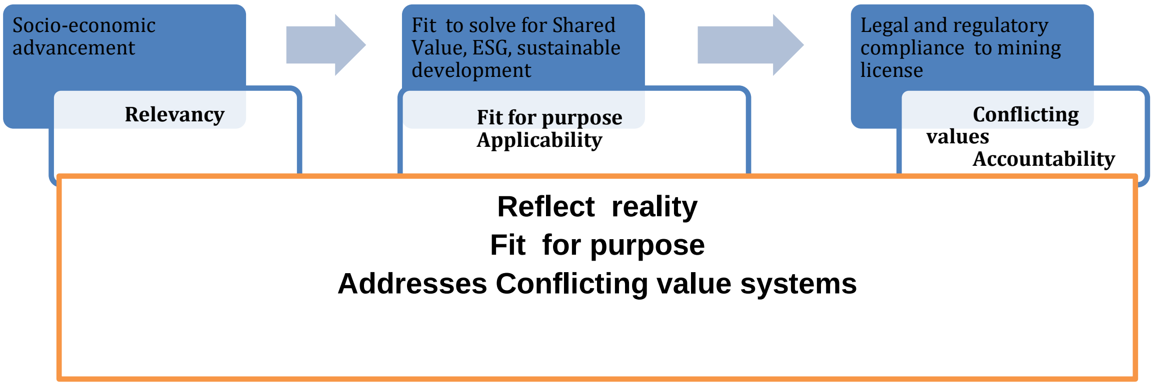

Figure 5-5: Skill Challenges of Robotics Adoption Strategy

"Grand challenges such as energy, water, and food scarcity limit our growing population's ability to live sustainably on Earth. Such complex societal challenges, which interconnect many human and natural systems, will require today's students to apply approaches that go beyond simple cause and effect" (Gilbert, 2018).

Understanding the ideologies behind robotics design is crucial to assessing its relevance in any system. This exercise reveals diverse worldviews shaping the technology. However, equipping adopters or researchers with the ability to comprehend these worldviews in context is a challenge. Adopting robotics demands making value judgements contextualised to a given situation. These skills, falling under "soft skills" for the 4.0 revolution, are not technical but are vital for this nuanced evaluation.

5.6 CONCLUSION

Critical Systems Thinking (CST) allows for viewing robotics development and adoption as part of a larger system rather than in isolation. It promotes understanding the interconnectedness and interdependencies within systems, leading to informed decisions on robotics adoption. It encourages cross-functional collaboration, long-term process improvement, and smooth transitions by addressing resistance to change and fostering communication.

The application of CST in robotics technology adoption involves investigating and surfacing underlying powers, ideologies, and worldviews driving the robotics technology applications within real-world contexts. It establishes relevance within specific worldviews, clarifies purpose and values, and then deploys methodologies to design processes, structures, and systems, including appropriate robotics technology variations for achieving relevancy.

CST ensures fit for purpose implementation and skills alignment for robotics technology. It advocates a unitary approach tobotics technology adoption, emphasising analysis of the powers and ideologies driving the intention, intelligence, and technology design. This is a crucial yet often overlooked aspect in studying and adopting Industry 4.0 technologies like automation and robotics.

Key attributes of CST that are relevant to robotics technology adoption include diversity driven decision-making, preservation of complementarism (holism) in both theory and methodology, and Total Systems Intervention, which embodies practical CST, promoting complementarity, sociological awareness, and commitment to human well-being and emancipation.

Skills in unpacking conflicting values, addressing misfits, and defining relevancy are vital for effective robotics technology utilisation in mining. Unpacking the ideologies behind robotics technology design lays the foundation for understanding relevance in any system or context and, therefore, becomes the basis for revealing diverse worldviews. Understanding these worldviews equips technology adopters and learners to assess the technology's applicability in context. These skills are not technical but fall under the umbrella of soft skills crucial for supporting the 4.0 revolution.(inclusive of grand challenges like energy, water, and food scarcity demand solutions)

5.6.1 Benefits of Using Critical Systems Thinking in Adoption of Robotics Technology

1. CST views robotics development and adoption as part of a larger system, not in isolation.
2. It promotes understanding of interconnectedness and interdependencies within systems, leading to informed decisions on robotics adoption.

3. CST encourages cross-functional collaboration, long-term process improvement, and smooth transitions by addressing resistance to change and fostering communication.

5.6.2 Use of Critical Systems Thinking Theory as a Framework for Adopting a Relevant, Responsible Mining-Based Adoption Strategy

1. Applying CST in robotics technology adoption involves investigating underlying powers, ideologies, and worldviews driving the robotics technology applications within real-world contexts.
2. CST ensures fit-for-purpose implementation and skills alignment for robotics technology.
3. It advocates a unitary approach to adoption, emphasizing analysis of the powers and ideologies driving the intention, intelligence, and technology design.

5.6.3 Key Attributes of CST Relevant to Robotics Technology Adoption

1. Diversity-driven decision-making.
2. Preservation of complementarity (holism) in both theory and methodology.
3. Total Systems Intervention, a CST application tool, promotes complementarity, sociological awareness, and commitment to human well-being and emancipation.

2.13 Skill Challenges for Adopting Robotics Technology

Automation and robotisation bring about the need for a new set of skills and diverse knowledge, constituting new challenges for today's industries (de Holando, 2024). Jackson (2010) summarises the skills of a critical systems thinker to include:

1. Not claiming to know the answer in advance,
2. Not peddling the same solution to all problems in all circumstances,
3. Seeking to be holistic,
4. Ensuring that theory both underpins practice and is tested in practice,
5. Asking who benefits from the knowledge and advice provided as part of their project, Putting ethical issues firmly on the agenda,
6. Testing the diversity of the tools available for use in the service of different rationalities, Clarifying the constitutive roles of functionalist, interpretive, emancipatory, and other forms of intervention, and
7. Learning how to facilitate reflective conversation at the meta-methodological level.

The World Economic Forum (2021) complements these skills with soft skills such as leadership, management, creativity, emotional intelligence, critical thinking skills, an active learner mindset, judgement and decision-making, interpersonal communications, leadership, diversity and cultural intelligence, technological skills, and the ability to embrace change.

Given the fact that by 2030 there will likely be a competence gap in the youth of today.(Purwanto, Hartono & Wahyuni 2023), the 4IR generation teacher's role is to build a generation of learners with competence, character, new literacy skills and higher order thinking skills. These skills are inclusive of the creative aspects, critical thinking, communication and collaboration. In addition ,given that creative thinking is expected to grow faster in the next five years than demand for analytical thinking. (Miah, Erdie-Gally, Dancs & Fekete-Farka, 2024, there is an urgent importance of strategies for adopting new skills in developing countries and reforming education with enhanced training curricula

There is therefore an urgent need to strengthen digital-based curriculum revitalization.(Miah, Erdie-Gally, Dancs & Fekete-Farka, 2024) Curriculum revitalization should be integrated with the basic values of resilience, adaptability, integrity, competence, and continuous improvement (Purwanto, Hartono & Wahyuni, 2023; Khan & Bari 2023) An appropriate education philosophy is the most important factor that can lead to the success of robot development and robot adoption (Ching, & Hsu, 2023; Khan & Bari 2023). The goal is to create a generation of high-level competence character and literacy to answer the challenges of the industrial revolution era.

The CT2.0 educational approach integrates Computational Thinking (CT) into STEM education, addressing its limitations by incorporating Systems Thinking (ST). This approach fosters inductive reasoning and context-aware problem-solving, preparing students to tackle both local and global challenges. CT and ST are mutually reinforcing, with ST enhancing CT in STEM education. Researchers are urged to address the reductionist nature of CT and broaden its contribution from other fields. Presenting ST as a cognitive skill can democratize the discipline, promoting holistic flexibility among practitioners

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Appendices

Questionnaire

I, Jill Carol Sesoko (student number 991241011), Mcomm in Leadership Studies student at the Graduate School of Business of the University of Kwazulu Natal-Westville campus, am undertaking research as part of fulfilment of qualification for the Mcomm degree. The aim of the research is to explore the skills challenges in adoption of robotics in the mining sector The results will be used to identify skill challenges hindering the adoption of robotics technologies in the mining sector and to recommend on how critical systems thinking can be used as a systems thinking based problem solving technique in exploring and addressing skill challenges faced in adoption of robotics technology.
The interview will take 40 minutes and it is conducted confidentially. The information will be used for academic analysis purposes only.

Section 1: Profile of the participant

1.1 Designation:

1.2 Age group :

20-24	
25-29	
30-34	
35-39	
40-44	
45-49	
50-54	
55-59	
60 years or older	

Section 2: Adoption of Robotics Technology

2.1 What do you see as the main drivers for the uptake of robotics technology?

2.2 What in your opinion are the benefits of robotics to South Africa's mining sector?

2.3 What would you say are the disadvantages of utilising robotics technology in the mining sector?

2.4 What in your opinion are the barriers to utilisation of the technology by the mining sector?

2.5 Please state to what extent you agree or disagree with the following statements:
1: Strongly agree, 2: Partly agree, 3: neither agree nor disagree, 4: partly disagree, 5: strongly disagree
The introduction of Robotics technology in the mining industry brings about the following:

Enhances job satisfaction	
Increase productivity	
Run more efficient operations,	
Manage risk	
Improve health and safety,	
Reduce the cost of maintenance and extraction,	
Increase skill requirements	
Intensify workload	
Adds complexity to the job	
Increases information overload	
Loss of job	
Other:	

Section 3: How to apply critical systems thinking in adoption of robotics technology

3.1 What do you think are the components of a holistic strategy in adopting robotics technology?

3.2 What in your opinion are the key principles of a people centric robotics adoption strategy?

3.3 How can mining companies achieve such a people centric strategy?

3.4 What do you think are the social challenges mining sector companies face when implementing robotics technology

3.5 How can mining companies create a shared value with host communities in order to ensure advancement of socio-economic conditions of the communities through adoption of robotics technology?

3.6 What in your opinion are the key components of localisation of robotics technology?

3.7 How would you describe the impact of robotics technology to sustainable development?

3.8 How does robotics technology affect sustainable development in the mining sector?

3.9 Do you think that automation and robotics technology will likely result in lower labour demand by mining companies?

Yes	No

3.10Please explain why?

3.11 if Yes, what do you think will be the consequences of this lower labour demand to the mining sector?

3.12 What can the mining sector do to avoid these consequences?

Section 4: Skills

4.1 What in your opinion are the skills required to achieve a people centric adoption of technology?

1: Important 2: critical

Skill	Description	Rating

4.2 What are the skills required to ensure that adoption of the technology advances the social and economic condition of host communities?

1: Important 2: critical

Skill	Description	Rating

4.3 What do you see as the skills that ensure localization of robotics technology in host communities?

1: Important 2: critical

Skill	Description	Rating

4.4 What are the technical skills that will drive the success of robotics technology into the future?

4.5Please rate the relevancy of the following soft skills in adoption of robotics technology
1: Irrelevant, 2: Partially relevant, 3: critical

Creativity: ability to generate, recognize new ideas, to do things, and to solve problems	
Emotional intelligence: ability to express and be cognisant of others' emotions. Empathy, integrity, and ability to work well with others	
Critical Thinking skills: ideal in the human -machine relation and collaboration for improved productivity	
Active learner mindset: Capabilities to actively learn and grow. willing to take new challenges, learn from mistakes and actively seek new knowledge	
Judgement and decision making: Human decision making will become more complex as machine driven information processing will continue to evolve and be complex	
Interpersonal communications: communicate and exchange information and meaning between people	
Leadership: ability to inspire, help and motivate. Identify talent and do better for the good of the bigger picture	
Diversity and cultural intelligence: ability to understand, respect and work with others who have a different way of seeing things	
Embrace change: ability to be agile, embrace and celebrate change	

Section 5: Skills Development

5.1 How can the above-mentioned skills (mentioned in section3) be developed at an early stage of high school education as part of sector-based education?

5.2 How can the skills mentioned in section 3 be developed at tertiary education or post matric mining training programs?

5.3 How can early talent skill development programs address people-oriented robotics technology

5.4 How can these skills (as mentioned above) be developed through other programs done in partnership with community skills development

Section 6: Strategy and Change management

6.1 Rate the following statement: 0 Statement is not true and nothing has been implemented, 1: Some discussion have taken place,2: Strategy and action plan in place, 3: Good and sustained progress is taking place, 4: statement is definitely true

Statement	Rate
1. Universities and other training institutions have the necessary training and development programs to support the effective and efficient implementation of the robotics technology	
2. Post matric career transitioning equips learners with a good understanding of robotics technology and its benefits in mining sector	
3. Robotics technology is bringing about career opportunities in the mining sector	
4. There is a clear strategy in curriculum development that solves for relevancy in use of robotics technology	
5. Current curriculum development and training initiatives have a clear strategy in place to align skill development and implementation of robotics technology with transformation, ESG goals and mining charter requirements	
6. There is clear strategy, vision and roadmap on future robotics skills requirements	
7. There is strategy in place to guide early talent roadmap for closing current and future robotics skill gaps	

8. There are clear process and structures that aligns host community development skills with current and future robotics technology skills of the company	
9. Host communities digital divide increases due to robotics technology utilisation by the mine	
10. Opportunities for host community's empowerment programs aligned to robotics technology are identified	

Section 7: Success

7.1 What in your opinion has made it possible for the implementation of robotics technology to be successful

7.2 How has robotics technology contributed positively to ESG (Environment, Social and Governance) goals

7.3 What in your opinion is the future of robotics technology in the mining sector

Thank you very much for time and cooperation
Jill Carol Sesoko
If you have any questions, please contact me on [redacted]

Informed Consent Letter 3C

UNIVERSITY OF KWAZULU-NATAL
GRADUATE SCHOOL OF BUSINESS AND LEADERSHIP

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI
Graduate School of Business and Leadership

Master of Commerce in Leadership Studies (MCLS) Research Project

Researcher: Jill Sesoko ([redacted]
Supervisor: Dr B.Z. Chummun (031 260 8943)
Research Office: Ms P. Ximba (031-260 3587)

Dear Respondent,

I Jill Carol Sesoko, student no. 991241011 an MCLS (Master of Commerce in Leadership Studies), student at the Graduate School of Business and Leadership, of the University of KwaZulu Natal. You cordially are invited to participate in a research project entitled "Investigating cell phone application for mini bus public transport in the township of Clermont; Durban".

The aim and purpose of this research is to investigate how critical systems thinking approach can be used as framework to enhance adoption of robotics technology in the mining sector to reach the goals of responsible mining. The results of the research will be used to identify the skills challenges when adopting robotics technology and to explore how these challenges can be addressed as part of integrated early talent development in order to achieve relevancy in utilisation of robotics technology

Through your participation I hope that the study will create the following benefits:

1. Achieve practical application of Critical Systems Thinking as a problem solving technique to find solutions for achieving relevancy, adaptability and applicability in adopting Robotics technology

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Research Office, Westville Campus
Govan Mbeki Building
Private Bag X 54001
Durban
4000

14 July 2022

Dear Sir / Madam

Re: Jill Sesoko MComm (Leadership Studies)

This letter hereby confirms that **Jill Sesoko student number 991241011** has been granted approval to collect data on her research studies titled **Exploring the skills challenges of robotics at Anglo American Platinum** for her research towards the MComm (Leadership Studies)

[redacted]

Pieter Strydom
Section Manager: Employee Development
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UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

09 February 2023

Jill Carol Sesoko (991241011)
Grad School Of Bus & Leadership
Westville Campus

Dear JC Sesoko,

Protocol reference number: HSSREC/00004671/2022
Project title: Exploring the skills challenges of robotics at Anglo American Platinum
Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 29 August 2022 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 09 February 2024.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

HSSREC is registered with the South African National Health Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/dd

Humanities and Social Sciences Research Ethics Committee
Postal Address: Private Bag X54001, Durban, 4000, South Africa
Telephone: +27 (0)31 260 8350/4557/3587 **Email:** hssrec@ukzn.ac.za **Website:** http://research.ukzn.ac.za/Research-Ethics

UNIVERSITY OF KWAZULU-NATAL
GRADUATE SCHOOL OF BUSINESS AND LEADERSHIP

Master of Business Administration (MBA) Research Project

Researcher: Jill Sesoko ([redacted])
Supervisor: Dr B.Z. Chummun (031 260 8943)
Research Office: Ms P. Ximba (031-260 3587)

CONSENT

I ………………………………………(full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.
I understand that I am at liberty to withdraw from the project at any time, should I desire to do so.

Signature of Participant: ——————— Date: ————————

NB: *Researcher's Copy*