RESEARCH STUDY TO INVESTIGATE THE NATURE OF DEMAND AND SKILLS SUPPLY REQUIRED WITH THE CHANGING TECHNOLOGY IN THE MINING AND MINERAL SECTOR

Final Report

(Inclusive of All Sub-sectors)

Version: *3.00D*

Date: *January 2024*

Author: *Redflank*

Table of Contents

List of Figures

List of Tables

List of Acronyms

4IR	Fourth Industrial Revolution
AI	Artificial Intelligence
APP	Annual Performance Plan
AR	Augmented Reality
ARPL	Artisan Recognition of Prior Learning
CLAS	Cement, Limestone, Aggregates, and Sand
CSIR	Council for Scientific and Industrial Research
DHET	Department of Higher Education and Training
DOIT	Diffusion of Innovation Theory
DMRE	Department of Mineral Resources and Energy
DTIC	Department of Trade, Industry, and Competition
ERRP	Economic Reconstruction and Recovery Plan
FET	Further Education and Training
HR	Human Resources
HTFV	Hard to Fill Vacancy
IT	Information Technology
MEMSA	Mining Equipment Manufacturers of South Africa
merSETA	Manufacturing, Engineering and Related Services Sector Education and Training Authority
MMS	Mining and Minerals Sector
MOU	Memorandum of Understanding
MQA	Mining Qualifications Authority
MRS	Market Research Society
NDP	National Development Plan
NSDP	National Skills Development Plan
OEM	Original Equipment Manufacturer
PGM	Platinum Group Metals
PLC	Programmable Logic Controllers
PSET	Post-School Education and Training
QCTO	Quality Council for Trades and Occupations
RDO	Rock Drill Operator
SAQA	South African Qualifications Authority
SETA	Sector Education and Training Authority
SHE&Q	Safety, Health, Environment and Quality
SMART	Specific, Measurable, Achievable, Relevant and Time-Bound
STEM	Science, Technology, Engineering and Mathematics
SP	Strategic Plan
SSP	Sector Skills Plan
ToR	Terms of Reference
TVET	Technical and Vocational Education and Training

UAV	Unmanned Aerial Vehicle
VR	Virtual Reality
WIL	Work Integrated Learning

Glossary of Terms

Terms	Definition
Upskilling	To provide someone (such as an employee) with more advanced skills through additional education and training.
Reskilling	The acquisition of new work-related skills by employees in a company that allows them to perform an existing activity in a different way or to take up a completely new activity.
Modernisation	The mining sector's adoption and integration of cutting-edge procedures, technologies, and practices in order to improve productivity, efficiency, and safety.
Mechanisation	The introduction and use of machinery and mechanical equipment to carry out a numbers of tasks that were previously done manually.
4IR	An era where people are using smart, connected and converged cyber, physical and biological systems and smart business models to define and reshape the social, economic and political spheres.
Technology	The use of scientific knowledge or processes in business, industry, manufacturing, etc
Industrial Revolution	A rapid major change in an economy marked by the general introduction of power-driven machinery or by an important change in the prevailing types and methods of use of such machines.
Artificial Intelligence (“AI”)	The ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings.
Cybersecurity	Measures taken to protect a person, organisation, or country and their computer information against crime or attacks carried out using the internet.
Robotics	Technology dealing with the design, construction, and operation of robots in automation.
Virtual reality (“VR”)	The use of computer modelling and simulation that enables a person to interact with an artificial three-dimensional (3-D) visual or other sensory environment.

Terms	Definition
Data Analytics	Data analytics is the collection, transformation, and organisation of data in order to draw conclusions, make predictions, and drive informed decision making.
Digital Transformation	Digital transformation is the integration of digital technology into all areas of a business, fundamentally changing how you operate and deliver value to customers
3D Modelling	3D modelling refers to the process of creating a three-dimensional representation of an object, whether inanimate or living, using specialised software.
3D Mapping	3D mapping, sometimes also referred to as photogrammetry, leverages aerial imagery to generate an accurate map that goes beyond the traditional flat, 2D representation by creating a more detailed and realistic depiction of the landscape or objects involved.
3D Printing	3D printing, in manufacturing, any of several processes for fabricating three-dimensional objects by layering two-dimensional cross sections sequentially, one on top of another.
Augmented reality (“AR”)	An enhanced version of the real physical world that is achieved through the use of digital visual elements, sound, or other sensory stimuli and delivered via technology.
Automation	Automatically controlled operation of an apparatus, process, or system by mechanical or electronic devices that take the place of human labour.
Big Data	Big data refers to extremely large and diverse collections of structured, unstructured, and semi-structured data that continues to grow exponentially over time.
Blockchain	A digital database containing information (such as records of financial transactions) that can be simultaneously used and shared within a large decentralised, publicly accessible network.
Internet of Things (IoT)	The Internet of Things (IoT) describes physical objects embedded with sensors and actuators that communicate with computing systems via wired or wireless networks—allowing the physical world to be digitally monitored or even controlled.

Terms	Definition
Real-time information management systems	A business computer system that responds to transactions by immediately updating the appropriate databases. Real-time information systems generate a response fast enough to prevent human operators from waiting very long.
Skills Demand	Skills that employers are actively seeking in the workforce as a result of technological advancements, industry trends, and economic changes.
Skills Supply	The pool of skills currently available in the labour market as a result of the education system, training programs, and other skill development interventions of the workforce.
Skills Shortages	An insufficiency in the supply of workers with specific skills to meet the demand in the labour market.
Skills Gaps/Imbalance/Mismatch	The difference between the skills that employers need and the skills that workers possess in the labour market.

Executive Summary

This report presents the findings from the research conducted aimed at investigating the nature of demand and skills supply required with the changing technology ("the Project or "the Research") in the Mining and Minerals sector ("MMS"), as well as recommendations that the Mining Qualifications Authority ("MQA") may consider moving forward.

The emergence of sophisticated technologies in the MMS has impacted the sector's operations, both in South Africa and globally. The modernisation[1] and mechanisation[2] of deep-level mining is a development that is expected to expose fewer employees to risk during deep-level operations while increasing productivity, safety and potentially reducing costs for the sector (Montiea, 2015). In addition, the global focus on reducing the environmental impact of mining activities highlighted by the dominant discourse of incorporating Environmental, Social and Governance principles has been deemed as a contributing factor in the modernisation and mechanisation of the industry. To decrease the carbon footprint of the mining industry, new and advanced technologies are required, which in turn require a workforce that has the necessary skills to operate these technologies (SA Mining, 2022). This has necessitated the upskilling and training of workers to facilitate the adoption of new technology in the sector.

While the sector has made significant efforts in upskilling, several challenges and gaps remain. The MQA (2020) highlighted that "a direct quantitative comparison between future demand and supply of skills in the MMS is not possible" with the data that is currently available. Furthermore, the sector faces significant challenges in improving the supply of currently scarce artisan and professional skills, some of which include, but are not limited to (MQA, 2020):

- The poor quality of secondary education (particularly in Mathematics and Physical Sciences);
- The inability of the sector to attract high-quality school leavers;
- Poor articulation of the Further Education and Training ("FET") programme with other qualifications; and
- The low throughput rates for both artisan learnerships and engineering qualifications.

Considering this context, this research aimed to investigate the current level of skill demand and supply within the MMS to identify the specific interventions that may be required to address specific skills shortages within the sector. Interventions aimed at

[1] Modernisation within the MMS context refers to the adoption or implementation of a 'new way of doing' in the mining environment. It typically involves the adoption and integration of cutting-edge processes, technologies, and practices aimed at improving productivity, efficiency and safety. For example, a particular mining operation may implement trackless mining as opposed to tracked mining, which would involve new technology, processes, and practices, as well as new ways of structuring and organising work (Mandela Mining Precinct, 2021).

[2] Mechanisation refers to the introduction of technology, machines, or automated devices to enable a process or task to be performed with minimal human intervention or assistance (Mandela Mining Precinct, 2021).

bridging the gap between skills demand and supply may prove to be critical to the future of the MMS, particularly when considering that an adequately capacitated workforce is a key driver which is imperative to the mechanisation and modernisation of the MMS.

Research Methodology

The approach adopted for this Project was aimed at understanding the current level of demand and skills supply within the MMS, considering the changing technology being introduced in the sector.

From a conceptual standpoint, the research approach included both qualitative[3] and quantitative[4] methodologies. As such, the Project adopted a mixed methods methodological approach which was aimed at gathering, collecting, and integrating data from both qualitative and quantitative sources. Adopting this approach proved useful, particularly in terms of overcoming the limitations associated with a single design methodology. The mixed methods approach adopted for this Project allowed Redflank to offer a more comprehensive understanding of the research topic, given that it allowed for the gathering and integration of multiple data points (i.e., both numerical and non-numerical data). Through the integration of both qualitative and quantitative data, the weaknesses of a single design methodology were overcome and ensured rigorous conclusions (Sharma, et al., 2023).

A key aspect of the research approach adopted for this Project involved the cross validation and triangulation of multiple data points, to ensure robust findings. The methods of triangulation adopted for this Project are detailed below:

- **Data Triangulation:** this refers to the simultaneous use of data from a variety of sources including interviews, surveys, focus groups, and relevant literature. Cross-referencing information gathered from these diverse sources ensured a comprehensive and robust understanding of the research topic, enhancing the credibility and validity of the findings. For example, the nature and extent of technological developments within the MMS were established initially from an analysis of literature, and then validated against findings from surveys, interviews and focus groups; with interviews and focus groups further exploring and assessing areas of technological developments and its impact on occupational profiling and skills supply and demand within the MMS.
- **Methodological Triangulation:** this entailed the use of various research methods, including interviews, surveys, focus groups and a literature review to respond to the same research topic. This form of triangulation was adopted to

[3] A qualitative research design is typically focused on gathering non-numerical data. This may include subjective data that provides potential justifications for specific phenomena and provides a more complex and/or a deeper view of the topic being explored. For example, the data gathered as part of interviews and focus groups is considered as qualitative (Wilson, et al., 2021).

[4] A quantitative research design is typically focused on gathering numerical data through research tools such as survey questionnaires. Quantitative designs often follow a traditional scientific method of gathering data (Wilson, et al., 2021).

strengthen the research design, which served to provide a more comprehensive and reliable findings.

- **Space Triangulation:** the Project included participants from different provinces to examine nuances relating to the impact of changing technologies based on their specific regional contexts.
- **Data Source Triangulation:** this was adopted through the integration of diverse data sources, such as in-depth interviews with various stakeholders such as Employees, Employer Affiliation Bodies, Labour Union representatives and Training Providers. This approach was employed to gain a comprehensive understanding of the research topic, ensuring a more robust analysis of the findings.

In addition to the adoption of a mixed methods approach, both desk-based and consultative (i.e., fieldwork) data collection methods were used to obtain the findings contained within this report. The desk-based research conducted consisted of:

- An in-depth literature review in order to obtain a baseline understanding of the MMS, the MMS value chains, and the factors influencing skills demand and supply dynamics within the MMS:
- A review of relevant reports including MQA's Sector Skills Plan (2023/24); Strategic plan (2020-2025); and APP (2023/24).

Fieldwork research included consultations with key stakeholders, and consisted of surveys, in-depth interviews and focus groups. The following table provides a breakdown of the number of completed consultations for the Project, per stakeholder type. A total of 445 consultations were completed.

Table 0-1: Completed Consultations[5]

Stakeholder	Completed Consultations
In-depth Interviews	
Companies across 9 sub-sectors	33
Employer Affiliation Bodies (e.g., AMIHRP, AMMSA etc.)	2
Labour/Union Representatives within the MMS	3
Training Providers within the MMS	22
Nelson Mandela Mining Precinct	1

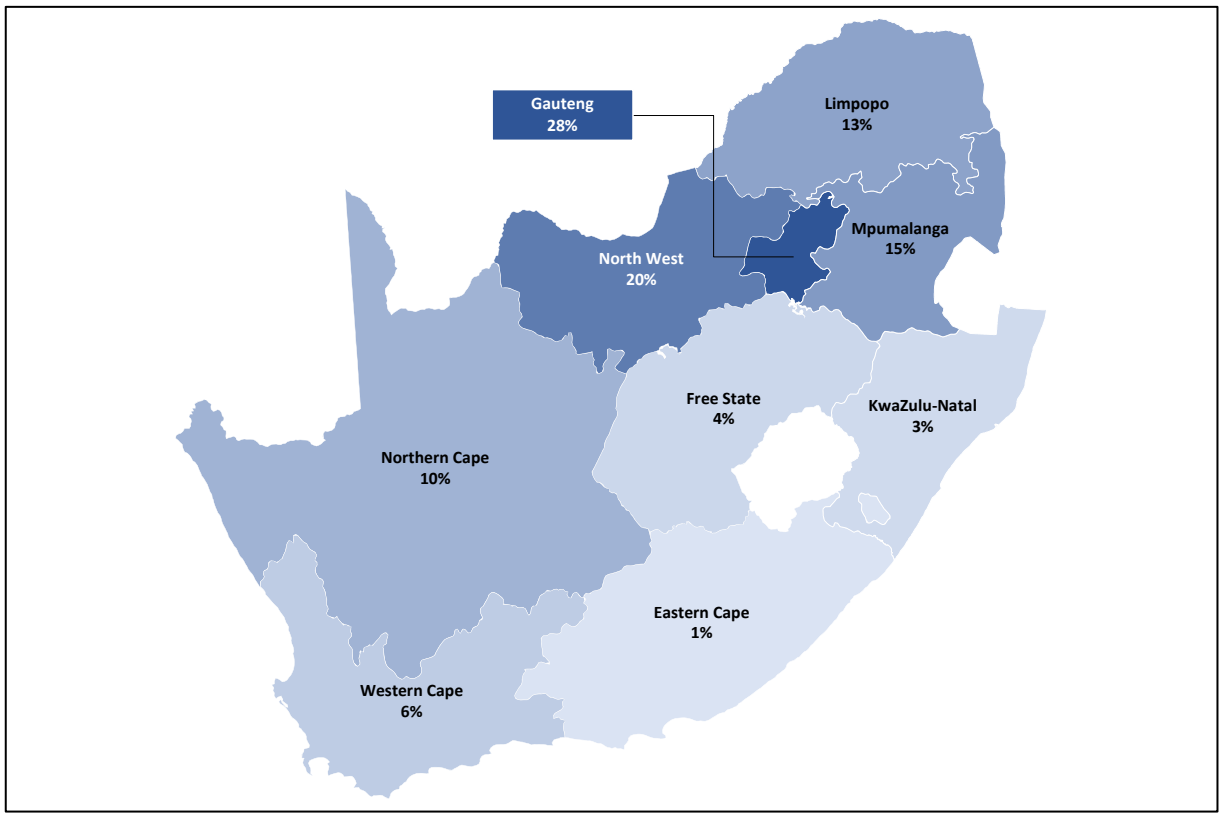
[5] While consultations were initially planned with Organised Labour Representatives, the Department of Mineral Resources and Energy ("DMRE") and related agencies, as well as the Department of Trade, Industry and Competition ("DTIC"), during further discussions with the Project Sponsor, it was agreed that as a result of the unavailability of some stakeholders and the number of consultations completed, consultations with these stakeholders would no longer be required.

Stakeholder	Completed Consultations
CSIR	1
MEMSA	1
Total	**63**
Surveys	
Employers	321
Training Providers	27
Total	**348**
Provincial Focus Groups	
Employers	7 with 34 participants
Total	**445**

Provincial Representation of Respondents

The figure below illustrates the provincial representation of the organisations that responded to the survey.

Figure 0-1: Provincial Representation of Respondents



Source: MQA Skills Demand and Supply Research, 2023

As can be seen above, of the 321 employers that participated in the survey, the majority were based in Gauteng (28%), North West (20%) and Mpumalanga (15%). On the other hand, only 3% of employers were located in KwaZulu-Natal, whilst only 1% were located in the Eastern Cape.

Research Findings

The findings emerging from the Project are outlined below. The research findings are grouped according to key focus areas.

Hard to Fill Vacancies ("HTFVs")

The research identified several occupations within the MMS that are currently hard to fill, namely:

- Mining operations manager;
- Engineering manager;
- Mechanical engineer; and
- Mining engineer.

In addition to the abovementioned occupations, input received from employers within the diamond mining sub-sector noted additional hard-to-fill vacancies such as Safety, Health, Environment and Quality ("SHE&Q") practitioner, diamond cutter, and diamond polisher.

Insights from qualitative consultations with MMS employers across several sub-sectors noted that recently qualified engineers find the MMS less attractive due to non-competitive salaries and a reluctance to work in remote or rural locations. Other challenges in filling these positions include a lack of qualified candidates (suggesting supply side challenges) and experienced candidates.

Impact of Changing Technology on the MMS

Data collected through this study suggests that while some organisations have embraced more sophisticated technologies, a significant portion of organisations within the sector have not fully adopted Fourth Industrial Revolution ("4IR") related technologies, which is primarily due to financial constraints. Financial constraints in this context relates to both the cost associated with purchasing and implementing more sophisticated technologies as well as the cost implications associated with the upskilling and reskilling of employees.

The research also indicated that smaller organisations in particular face challenges in affording and implementing new technologies and upskilling employees, with certain employers from small organisations noting that the cost of training on 4IR skills outweighs the perceived benefits.

Furthermore, while several employers acknowledged that the implementation of more sophisticated technologies pose several benefits for their organisations, such as

improved productivity and efficiency, the general sentiment emerging from the research is that the sector should approach the implementation of 4IR technologies in a manner that balances these organisational benefits with employee interests.

Skills Gaps

Key skills gaps identified in the MMS include management, leadership, digital literacy, technical, and advanced IT and software skills. Leadership and management skills gaps are prevalent across most sub-sectors. Similarly, digital literacy is recognized as a significant skills gap across all sub-sectors except coal mining and cement, limestone, aggregates and sand ("CLAS") mining sub-sectors.

Regarding skills gaps specific to certain sub-sectors, the findings indicated that there are numerical modelling skills gaps in the diamond processing and Platinum Group Metals ("PGM") mining sub-sectors.

Lack of basic digital skills and overall numeracy and literacy skills among employees pose challenges to upskilling efforts as these are foundational skills upon which more advanced skills must be built.

Impact of Changing Technology on Occupations and Skills

The research has indicated that a considerable portion of organisations within the MMS need to upskill or reskill employees to accommodate more sophisticated technologies, with 86% of surveyed employers indicating that their employees require upskilling and/or reskilling for the operation of newly introduced technologies.

Regarding the impact of changing technology on specific occupations, consulted employers indicated that machine operators will most likely need technical and digital skills to adapt to more sophisticated technologies. It was also noted that employees in managerial and/or supervisory positions may need to adapt their skillsets, given that the introduction of more sophisticated technologies may now require individuals occupying these positions to not only manage people, but processes as well.

Skills and Occupations in Demand

In the short-term, key soft skills in demand include judgment and decision making, change management, innovative thinking, problem-solving, and leadership. The demand for skills related to adaptability will also increase in the short-term.

On the other hand, computer literacy, data analytics, digital literacy, and project management skills were highlighted as crucial technical skills for which demand will increase in the short-term.

In line with the above, occupations expected to be in demand include data analysts, information systems specialists, application developers, electrical engineers, and workplace reform (i.e., change management) specialists.

Awareness around 4IR and Changing Technology

The research revealed that a lack of awareness amongst employers and training providers regarding the benefits and implications of changing technology hinders its

implementation. Many employers do not fully comprehend the long-term benefits of 4IR, citing the need for research to be conducted that considers the benefits associated with new technologies against the costs of implementing said technology. The lack of awareness around the implications of the implementation of new technology also impacts employee buy-in, with key stakeholders (such as employers and employer affiliation bodies) noting that there is reluctance amongst employees as it pertains to embracing new technologies, which is underpinned by the negative stigma associated with new technologies and its potential impact on job losses within the MMS.

Impact of Changing Technology on Skills Development Interventions

It was found that existing learning materials in the MMS market have not been updated to align with changing technologies, necessitating an urgent update of said learning materials. In addition to updating learning material, several employers emphasised the need for standardised learning material to ensure consistency in terms of the competency of individuals who successfully participate in skills development interventions.

From the perspective of training providers, several organisations noted that the MQA should consider facilitating increased information sharing in order to ensure that their learning material can be adapted/updated to align with the latest developments within the sector as it relates to changing technology.

External training providers face challenges in implementing e-learning due to deficiencies in numeracy, literacy, and digital skills among MMS employees.

Current Skills Development Interventions Available on the MMS Market

A significant number of training providers offer interventions aligned with conventional MMS practices (as opposed to expected innovations) due to funding constraints and a lack of qualified assessors. Furthermore, training for 4IR technologies is limited, with a notable absence of interventions in the external market.

Positive Practices

Stakeholders commended the MQA for effectively engaging with the MMS, gathering feedback, and adapting strategies based on stakeholder feedback to address skill development needs. Communication and ongoing engagement with stakeholders were also highlighted as positive practices.

Areas for Improvement

The research flagged several areas of improvement for the MQA to consider. Consulted employers and training providers indicated that the MQA should consider:

- Expanding the types of skills and qualifications supported to ensure that skills demands within the sector are met;
- Increasing communication on available 4IR related training initiatives, and fostering awareness of 4IR technologies; and

- Developing a central communication platform for training providers in order to facilitate the swift dissemination of relevant information pertaining to 4IR developments within the MMS.

SMART Recommendations

The below provides a set of implementable recommendations, drafted in terms of the SMART criteria. We note that the degree of implementation of each recommendation will be dependent on the MQA's available budget and should be considered within this context.

Recommendation 1: Increase MMS Sector Attractiveness at School Level

To address the issue of a lack of qualified candidates, the MQA should implement targeted career awareness campaigns in schools and universities to inform students about the opportunities and benefits of pursuing careers in the mining sector. The MQA may also consider distributing information packs, to schools, with the above indicated relevant content so that schools can further distribute this information to students.

Recommendation 2: Develop Talent Attraction Strategies Based on Best Practices

To address the limited supply of suitably qualified candidates within specific geographies, the MQA should commission a research study aimed at establishing best practices on attracting suitably qualified and experienced talent to the MMS. The findings of this research should be disseminated to MMS employers.

Recommendation 3: Develop Clear Career Development Pathways for MMS Employees

To enhance the professional growth and retention of skilled talent within the MMS, the MQA, in collaboration with employers, should establish transparent career development pathways for MMS employees. By fostering a supportive environment for professional development, the MQA can incentivize talented individuals to commit to long-term careers within the MMS, ultimately contributing to its sustained growth and success.

Recommendation 4: Continued Focus on Developing Basic Numeracy and Literacy Skills

To address the lack of basic numeracy and literacy skills amongst MMS employees, it is recommended that the MQA continues to prioritise the provisioning of funding for Foundational Learning Competence Programmes and Adult Education and Training Programmes. While it is noted that the MQA has made significant progress in improving the level of basic numeracy and literacy skills through its Foundational Learning Competence and Adult Education and Training programmes and is attempting to focus more on providing funding for digital elementary skills, the findings indicate that the lack of basic numeracy skills is still a concern for employers attempting to train their employees. Basic literacy and numeracy skills are foundational and

should be seen as critical 'building blocks' which will allow employees to engage in more advanced training related to 4IR skills.

In addition to the above, given that employees belonging to specific occupational groups (e.g., such as plant and machine operators and assemblers) appear to be at risk of being impacted by the implementation of 4IR technologies, the MQA should consider revising discretionary grant funding guidelines for AET and FLC programmes to prioritise the enrolment of individuals belonging to the abovementioned occupational groups into said programmes. This may serve to equip these individuals with basic numeracy and literacy skills which may allow them to participate in more advanced training associated with digital, computer, and 4IR related skills.

Recommendation 5: Continued Provisioning of Funding for Artisan Recognition of Prior Learning ("ARPL") Programmes

Given that a large portion of MMS employees do not have qualifications, the MQA should continue the provisioning of funding for ARPL Programmes, in order to ensure that MMS employees are able to attain their trade qualifications.

Recommendation 6: Increase the Development of Soft Skills within the MMS

To address soft skills gaps, as well as to meet the demand as it pertains to the soft skills for which demand will increase within 1 to 2 years, the MQA should consider reviewing and redesigning the existing technical curriculum to include opportunities for students to practice and develop soft skills. This is cognisant of the fact that there is no specific training for the development of soft skills, which necessitates the development of these skills through an integrated approach as part of technical training.

Recommendation 7: Accredit Course Outcomes to Improve Speed of Accreditation

The MQA should consider quality assuring learning outcomes instead of activities by setting standardised tests for short programmes as an alternative to going through the complete accreditation process for all short programmes (which is not practically possible). Learners with unaccredited short programme certificates could register directly on the QCTO/ SETA website to be assessed on the closest accredited programme covering the skills they learned in the unaccredited programme. This would bridge the gap between the high demand for short programmes and the low supply of MQA accredited short programmes.

Recommendation 8: Increase Awareness Amongst Training Providers Regarding the Latest 4IR Related Developments

To ensure that training providers can provide training on 4IR-related technologies, it is critical that they are kept up to date with emerging 4IR-related trends and the implications that these trends will have on skills training in terms of content and delivery. This may be achieved through comprehensive information sharing campaigns designed to educate and update training providers on the 4IR-related changes

occurring within the sector, and the broad changes to skills training requirements that may be adopted in the future.

Recommendation 9: Conduct a Review of the Resources Available to Training Providers

The MQA should commission a study aimed at conducting a review of the resources and equipment required by training providers to effectively provide 4IR-related training. This is to ensure that the training providers are well capacitated, both through technological as well as human resources, to be able to provide said training. Once this review is done, the feasibility of providing additional funding specifically for 4IR-related training based on the review may be assessed and revised accordingly.

Recommendation 10: Develop a Strategy for Cross-Sector Collaboration

The MQA should develop a strategy aimed at forming partnerships with other SETAs that have overlapping interests. Once a strategy has been developed, the MQA should consider entering into Memorandum of Understanding ("MOU") agreements with identified SETAs.

Recommendation 11: Incorporate Digital Skills into Training Programmes

To facilitate the transition from manual operations to workforces monitoring computers or operating the software controlling the technologies implemented and to meet the evolving demands of the job market, digital skills should be incorporated into training programmes.

Additionally, considering the importance of basic digital literacy, the MQA may consider incorporating a basic digital literacy module and unit standard to AET and FLC programmes as well as programmes anticipated to be most impacted by technological developments. This intervention is premised on assessing MQA funded skills programmes to determine which programmes are associated with jobs/processes/activities likely to be impacted by 4IR.

Furthermore, to increase the level of computer and digital literacy in the medium to long term, the MQA's quality assurance unit may also consider developing and incorporating a basic computer and digital literacy module and unit standard (s) as part of the learning packs/curriculum modules that the unit already develops for training providers.

Recommendation 12: Conduct Regular Monitoring of Training Programmes and Skills Initiatives

Given that the occupational and skills needs of the sector are continuously evolving, the MQA should regularly monitor the success and effectiveness of training programmes in meeting the projected skills and occupational demands. To achieve this, the MQA should clearly define a goal of regularly monitoring the success and effectiveness of training programmes in meeting the projected skills and occupational demands within the sector by establishing measurable indicators to assess the success and effectiveness of training programmes.

Recommendation 13: Establish Collaborative Forums Between Organisations and Original Equipment Manufacturers ("OEMs")

To ensure seamless integration and optimal utilisation of resources supplied by OEMs to mining operations, the MQA may consider facilitating partnerships between OEMs and MMS organisations, through collaborative forums, to involve OEMs in the skills development process and establish a direct link between the skills required by the workforce and the technological requirements of the equipment. This proactive approach can enhance communication, understanding, and coordination between OEMs and MMS organizations in the skills development process.

Recommendation 14: Adopt and Implement the Framework for Future Skills Needs Identification

Once the Framework for Future Skills Needs Identification is adopted, the MQA should implement the framework that has been developed. The framework is envisioned to provide MQA with practical steps on how to keep abreast with the technological changes occurring in the MMS, and by extension, how to anticipate future skills needs.

1 Introduction

This Report, drafted by Redflank on behalf of the MQA, presents the findings from the research aimed at investigating the current level of demand and skills supply within the MMS considering the changing technology within the sector ("the Project" or "the Study"). The report analyses feedback received from key stakeholders (i.e., employers and training providers across all MMS sub-sectors, employer affiliation bodies, labour unions, and other key stakeholders within the MMS such as representatives from the Mandela Mining Precinct, CSIR and MEMSA) regarding the current level of skills demand and supply and explores how changing technology has impacted occupations and skills within the MMS. The report also provides practical recommendations on how the MQA can respond to skills demands within the MMS.

1.1 Project Background

The emergence of sophisticated technologies in the MMS has impacted the sector's operations, both in South Africa and globally. The modernisation[6] and mechanisation[7] of deep-level mining is a development that is expected to expose fewer employees to risk during deep-level operations while increasing productivity, safety and potentially reducing costs for the sector (Montiea, 2015). In addition, the global focus on reducing the environmental impact of mining activities highlighted by the dominant discourse of incorporating Environmental, Social and Governance principles has been deemed as a contributing factor in the modernisation and mechanisation of the industry. To decrease the carbon footprint of the mining industry, new and advanced technologies are required, which in turn require a workforce that has the necessary skills to operate these technologies (SA Mining, 2022). This has necessitated the upskilling and training of workers to facilitate the adoption of new technology in the sector.

While the sector has made significant efforts in upskilling, several challenges and gaps in the research remain. The MQA (2020) highlighted that "a direct quantitative comparison between future demand and supply of skills in the MMS is not possible" with the data that is currently available. Furthermore, the sector faces significant challenges in improving the supply of currently scarce artisan and professional skills, some of which include, but are not limited to (MQA, 2020):

- The poor quality of secondary education (particularly in Mathematics and Physical Sciences);
- The inability of the sector to attract high-quality school leavers;
- Poor articulation of the FET programme with other qualifications; and

[6] Modernisation within the MMS context refers to the adoption or implementation of a 'new way of doing' in the mining environment. It typically involves the adoption and integration of cutting edge processes, technologies, and practices aimed at improving productivity, efficiency and safety. For example, a particular mining operation may implement trackless mining as opposed to tracked mining, which would involve new technology, processes, and practices, as well as new ways of structuring and organising work (Mandela Mining Precinct, 2021).

[7] Mechanisation refers to the introduction of technology, machines, or automated devices to enable a process or task to be performed with minimal human intervention or assistance (Mandela Mining Precinct, 2021).

- The low throughput rates for both artisan learnerships and engineering qualifications.

Considering this context, it is critical to investigate the current level of skill demand and supply within the MMS to identify the specific interventions that may be required to address specific skills shortages within the sector. Interventions aimed at bridging the gap between skills demand and supply may prove to be critical to the future of the MMS, particularly when considering that an adequately capacitated workforce is a key driver which is imperative to the mechanisation and modernisation of the MMS.

1.2 Research Objectives

The research objectives of the Project included the following:

- Determining the nature of skills demand and supply required with the changing technology in the MMS;
- Outlining the extent and nature of the current skills supply (education and training provision);
- Identifying the skills mismatches between supply and demand;
- Outlining in detail the nature and type of skills development interventions that can be implemented to address the identified skills mismatches;
- Identifying and outline various ways of leveraging on cross-sectoral training to address the skills demand in the MMS; and
- Identifying Specific, Measurable, Achievable, Relevant and Time-Bound ("SMART") recommendations for MQA to implement over the short, medium, and long-term period.

1.3 Significance of the Study

This research study is crucial for aligning industry skills needs with the supply of skills in the sector. By investigating skills demand and supply in the mining and minerals sector, this study addresses the critical issue of skills mismatches within the sector and proposes the nature and types of skills development and cross-sectoral training interventions to address the changing skills demands within the sector. This will in turn ensure that the MQA is able to make informed decisions and thereby contribute to building a skilled workforce, support continuous learning, and foster the sector's growth and sustainability amid changing technological landscapes.

2 Research Methodology

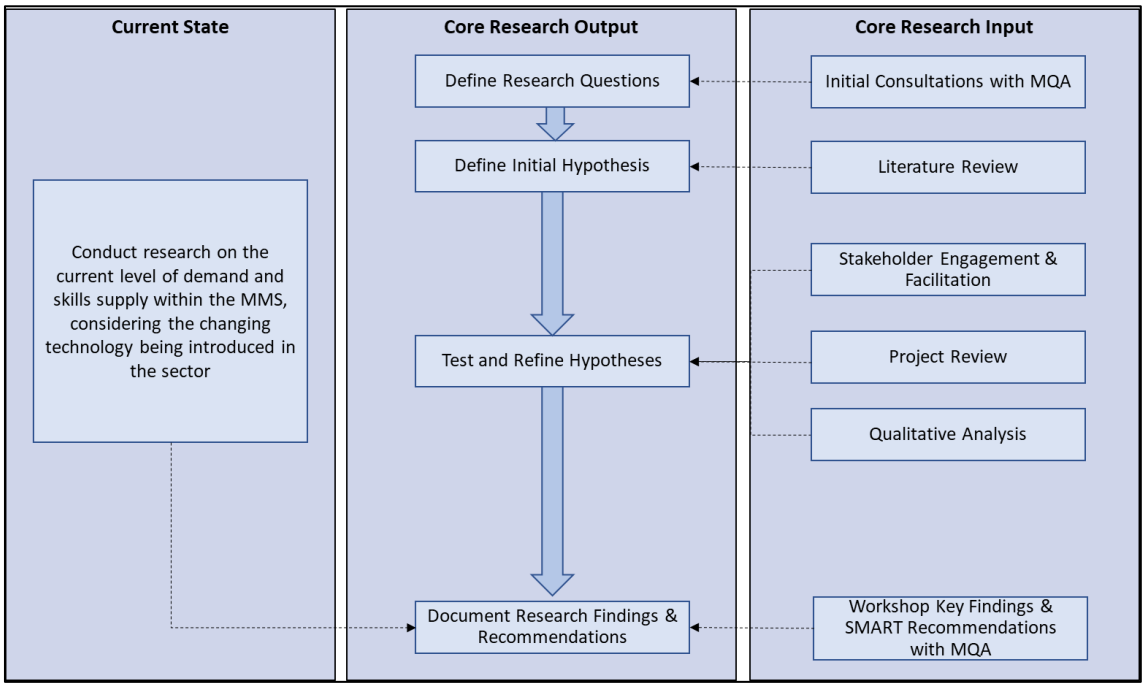
The following sections provide details on the methodology adopted for the Project.

2.1 Research Design

From a conceptual standpoint, a mixed methods methodology was adopted, which integrated data from both qualitative[8] and quantitative[9] sources, in order to gain a comprehensive understanding of the current levels of demand and skills supply within the MMS considering changing technology. This mixed methods approach allowed for the analysis of multiple data points (i.e., both numerical and non-numerical data) and assisted in the weaknesses of a single design methodology, thereby ensuring rigorous conclusions (Sharma, et al., 2023).

The figure below illustrates the key components of the methodology adopted for this Project.

Figure 2-1: Conceptual Approach



2.2 Sampling

An important element of this Project was ensuring appropriate sampling methods were adopted during the data collection process. Sampling is defined as the process of choosing a group of participants from a specific population and studying the behaviour, characteristics, or traits to arrive at meaningful conclusions which then allow for the development of appropriate recommendations (Adwok, 2015). The sub-sections that

[8] A qualitative research design is typically focused on gathering non-numerical data. This may include subjective data that provides potential justifications for specific phenomena and provides a more complex and/or a deeper view of the topic being explored. For example, the data gathered as part of interviews and focus groups is considered as qualitative (Wilson, et al., 2021).

[9] A quantitative research design is typically focused on gathering numerical data through research tools such as survey questionnaires. Quantitative designs often follow a traditional scientific method of gathering data (Wilson, et al., 2021).

follow outline the sampling techniques adopted in order to select participants (i.e. target population[10]) for this Project, including purposive sampling, and snowball sampling.

2.2.1 Purposive Sampling

Purposive sampling is a non-random sampling method which involves researchers intentionally selecting specific individuals or entities from a population based on specific characteristics or qualities (Nikolopoulou, 2023). Using purposive sampling allows researchers to select all parties relevant to the study and allows for the ability to target niche demographics to obtain specific data points.

In order to conduct purposive sampling, the first step relates to defining the purpose and objectives of the study in order to facilitate the participant selection. Once this has been defined, the criteria to be used in order to select participants should be detailed – in the context of this Project, the criteria adopted for participant selection was directly related to the research objectives and were used to identify the individuals that participated in interviews and focus groups. The selection criteria are outlined in Table 2-1 below. Once the criteria has been defined the sample may be identified based on this criteria (Heath, 2023):

As mentioned above, purposive sampling techniques were used to select participants for in-depth interviews and focus groups, based on the requirements included in the table below.

Table 2-1: Purposive Sampling

Data Collection Tools	Stakeholder Type	Purposive Sample's Criteria
Interviews	Companies across 9 sub-sectors	• Sub-sector • Size of organisation
	Employer Affiliation Bodies (e.g., AMIHRP, AMMSA etc.)	• Relevance to project
	Labour/Union Representatives within the MMS	• Relevance to project
	Training Providers within the MMS (2 per sub-sector)	• Sub-sector • Geographical location
	Nelson Mandela Mining Precinct	• Relevance to project
	CSIR	• Relevance to project

[10] The target population included Employers and Training Providers across the 9 sub-sectors, Employer Affiliation Bodies, Labour/Union Representatives, the Nelson Mandela Mining Precinct, CSIR and MEMSA.

Data Collection Tools	Stakeholder Type	Purposive Sample's Criteria
	MEMSA	• Relevance to project
Provincial Focus Groups	All relevant stakeholders	• Geographical location

2.2.2 Snowball Sampling

In order to further enhance stakeholder participation in the study, through the electronic surveys and in-depth interviews, snowball sampling was also employed. As part of this non-probability sampling methodology, new participants were selected based on referrals from existing study participants. In order to apply this sampling methodology in the context of this project, upon conclusion of the interview and focus group consultations, existing participants were requested to invite individuals to participate in the study by either providing their contact details so that the new participants may be requested to complete a survey or participate in an interview, or sharing the survey link with new participants so that they could also provide their input. This approach facilitated the inclusion of key stakeholders such as employer representatives on the operations side of mining.

2.3 Instrumentation

In order to collect primary data as part of this project, participants were requested to provide input via electronic surveys, in-depth interviews and focus groups.

2.3.1 In-Depth Interviews

In-depth interviews were conducted to explore key themes related to the study in a more qualitative manner. The intention of these interviews was not to collect numerical data, but to explore key opportunities and obstacles faced by employers and organisations as it pertained to the adoption of changing technology within the MMS and to document what participants view as key impacts/trends that need to be considered as it pertains to skills demand and supply. A sample of stakeholders, selected in accordance with the criteria defined as part of the purposive sampling process, were contacted and requested to participate in interviews. As part of this, prospective participants were informed about the Project background and the purpose of the interview and were asked whether they were willing to participate.

2.3.2 Electronic Surveys

In order to facilitate the completion of surveys, the survey questionnaire was drafted and administered through an online survey platform, Survey Monkey. An email containing the Project description, the purpose of the survey and a link to the survey

was distributed to all stakeholders (i.e., employers and training providers) contained in a mailing list (i.e., the research sample) that contained the email addresses of the stakeholders. The recipients were requested to complete the survey online by a specific date.

The survey sought to gain an understanding of various key themes related to the research topic, including:

- The current skills demand and supply dynamics within the MMS;
- The impact of changing technology on skills requirements in the MMS;
- The current as well as planned adoption of more sophisticated technologies across all MMS sub-sectors;
- Factors preventing organisations within the MMS from adopting more sophisticated technologies;
- The extent to which training providers are capacitated to provide training on new and emerging 4IR related skills;
- Forms of support required by employers in order to implement technological innovations within their operations; and
- Forms of support required by training providers in order to be able to provide 4IR-related skills training.

2.3.3 Focus Groups

As part of the focus groups consultations, a sample of stakeholders (selected through random sampling) were contacted telephonically to ask them if they were willing to participate in a focus group. These focus groups were held both in-person and virtually and were conducted across all provinces.

The purpose of these focus groups was to determine the level of adoption of more sophisticated technologies within the MMS and explore the anticipated impact of these technologies on the sector from the perspective of skills and occupations. Discussions in the focus groups were mainly focused on current and future changes in mining operations and activities as a result of changing technologies and understanding how organisations adapted to these changes. The focus groups also explored the changing occupational landscape, exploring the nature of changes in specific occupations brought about by changing technology. Furthermore, focus group discussions examined current skills gaps, reflected on the influence of changing technology on the sector's skills requirements, explored challenges that are anticipated to impact on workforces and gathered key input on how employers may be supported in this regard, as well as the capacity of skills delivery systems in ensuring that the MMS workforce has the necessary skills.

Due to the level of mining related business being conducted in the respective provinces and the number of employers located in the provinces, focus groups in Gauteng,

Northern Cape, Mpumalanga and the North West were conducted in-person. Focus groups in the remaining provinces (viz. Eastern Cape, Free State, Western Cape, KwaZulu-Natal and Limpopo) were conducted through virtual platform (using MS Teams) across three sessions. The first virtual focus group included individuals from Eastern Cape and Free State and was combined due to the limited number of contact details available. Following this, a second virtual focus group was hosted with participants from Western Cape and KwaZulu-Natal. These provinces were also grouped due to the limited number of contact details available. A third virtual focus group was conducted for participants from the Limpopo province.

2.4 Data Collection

The findings contained in this report have been developed based on input provided through both desk-based and consultative (i.e., fieldwork) data collection methods. The desk-based research included conducting an in-depth literature review in order to obtain a baseline understanding of the MMS, the MMS value chains, and the factors influencing skills demand and supply dynamics within the MMS, which involved reviewing relevant reports including MQA's Sector Skills Plan (2023/24); Strategic plan (2020-2025); and APP (2023/24).

The fieldwork conducted as part of this project included consultations with key stakeholders through surveys, in-depth interviews and focus groups. The following table provides the number of completed consultations for the Project. A total of 445 consultations were completed.

Table 2-2: Completed Consultations[11]

Stakeholder	Completed Consultations
In-depth Interviews	
Companies across 9 sub-sectors	33
Employer Affiliation Bodies (e.g., AMIHRP, AMMSA etc.)	2
Labour/Union Representatives within the MMS	3
Training Providers within the MMS	22
Nelson Mandela Mining Precinct	1
CSIR	1
MEMSA	1
Total	**63**

[11] While consultations were initially planned with Organised Labour Representatives, DMRE and related agencies, as well as the DTIC, during further discussions with the Project Sponsor, it was agreed that as a result of the unavailability of some stakeholders and the number of consultations completed, consultations with these stakeholders would no longer be required.

Stakeholder	Completed Consultations
Surveys	
Employers	321
Training Providers	27
Total	**348**
Provincial Focus Groups	
Employers	7 with 34 participants
Total	**445**

2.4.1 Employer Interviews

In-depth interviews were conducted with numerous representatives from employers within the MMS. Interviews were conducted with Skills Development Facilitators ("SDFs"), Human Resource Development ("HRD") Managers, and Learning and Development Managers. The following table outlines the designation of the representatives.

Table 2-3: Employer Interview Participant Details

Participant #	Designation
1	HRD Manager
2	Learning and Development Manager
3	HRD Manager
4	SDF
5	Training Manager
6	SDF
7	SDF
8	Owner
9	SDF
10	HRD Practitioner
11	HR Manager
12	• HRD Coordinator • Education, Training and Development Manager

Participant #	Designation
13	HRD Manager
14	HRD Manager
15	SDF
16	SDF
17	Training Superintendent
18	HRD Manager
19	Talent Management Specialist
20	SDF
21	Director
22	Training and Development Manager
23	Compliance Manager and Head of HR
24	SDF
25	HR Consultant
26	HR Generalist
27	HR Officer
28	Business Development Manager
29	HR Consultant
30	Talent Management Specialist
31	HR Business Partner
32	HR Manager
33	Operations Director

2.4.2 Training Provider Interviews

In-depth interviews were also conducted with representatives from different MMS training providers, including SDFs, training managers, and project coordinators. The following table outlines the designation of the representatives who participated in training provider interviews.

Table 2-4: Training Provider Interview Participant Details

Participant #	Designation
1	Director

Participant #	Designation
2	SDF
3	SDF
4	Not Specified
5	Training Manager
6	Managing Director
7	HRD Superintendent
8	COO
9	SDF
10	CEO
11	Centre Manager
12	Project Coordinator
13	Managing Director
14	Managing Director
15	SDF
16	SDF
17	Training Head
18	Managing Director
19	Managing Director
20	General and Administrative Manager
21	Founder and Director
22	Not Specified

2.5 Analysis of Data

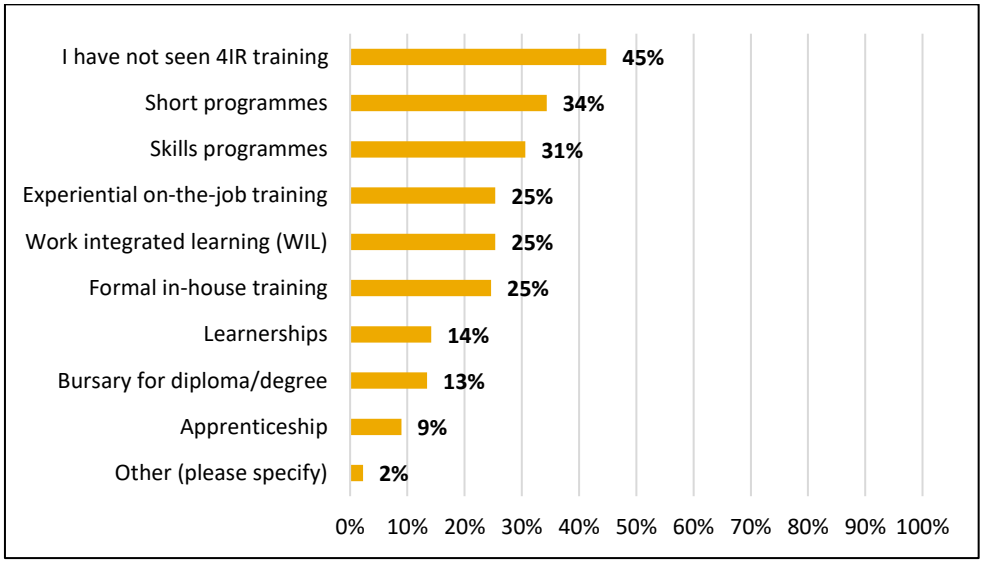
As mentioned, electronic surveys were conducted in order to collect quantitative data. This data is presented throughout this Report, either in the form of graphs or a table. The majority of the graphs presented measure the percentage of respondents who selected a specific option/s over the total number of respondents for that question. Figure 2-2 below provides an illustrative sample of survey results.

Figure 2-2: Illustrative Sample Survey Results

If you have seen training on 4IR skills, which of the following forms of training worked best? (Please select all that apply)	
Other (please specify)	2%
Apprenticeship	9%
Bursary for diploma/degree	13%
Learnerships	14%
Formal in-house training	25%
Work integrated learning (WIL)	25%
Experiential on-the-job training	25%
Skills programmes	31%
Short programmes	34%
I have not seen 4IR training	45%

This data would then be presented as indicated in the illustrative figure below.

Figure 2-3: Illustrative Sample Graph



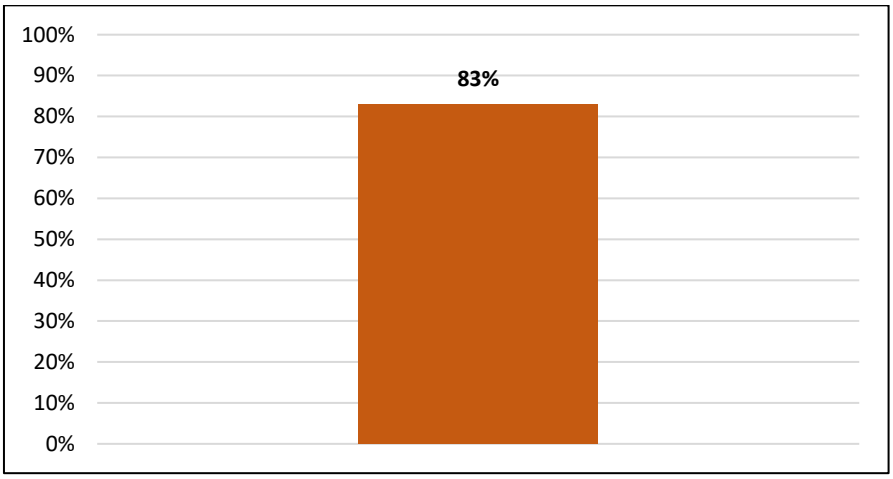
Further to the above, a selection of survey questions were based on a Likert scale. Likert-type or frequency scales use fixed choice response formats and are designed to measure attitudes or opinions (Bowling, 1997). An example of a Likert scale adopted as part of this study and used in this report is the scale used to measure the extent of a state, ranging from “not at all” to “completely” (see below), for instance, the extent to which the adoption of 4IR innovations in the industry is being limited by a lack of relevant skills.

Table 2-5: Likert Scale

Likert Scales of Extent				
Not at All	Minimally	Somewhat	Significantly	Completely

Questions based on a Likert scale, were presented in graphs as a sum of the positive responses (i.e. the sum of “Somewhat”, “Significantly”, and “Completely”), as illustrated below.

Figure 2-4: Illustrative Sample Graph



In order to add depth to the quantitative results, the qualitative data gathered through in-depth interviews and focus groups was also assessed for this Project. This involved collating the data into a consolidated excel spreadsheet and conducting a thematic analysis in order to identify pertinent themes. Key qualitative insights from the collated responses were extracted and included in relevant sections to support and validate the quantitative findings emerging from the data.

2.5.1 Triangulation

In order to ensure robust research findings, the cross validation and triangulation of multiple data points was conducted. The methods of triangulation are detailed below:

- **Data Triangulation:** this refers to the simultaneous use of data from various sources such as interviews, surveys, focus groups, and relevant literature. Cross-referencing information gathered from multiple sources ensured a comprehensive understanding of the research topic, enhancing the credibility and validity of the findings. For example, the nature and extent of technological developments within the MMS were established initially from an analysis of literature, and then validated against findings from surveys, interviews and focus groups; with interviews and focus groups further exploring and assessing areas of technological developments and its impact on occupational profiling and skills supply and demand within the MMS.
- **Methodological Triangulation:** this entailed the use of various research methods, including interviews, surveys, focus groups and a literature review to respond to the same research topic. This form of triangulation provided a more comprehensive and reliable findings and was adopted to strengthen the research design.

- **Space Triangulation:** participants from different provinces were included in the Project which allowed for the examination of nuances relating to the topics at hand based on their specific regional contexts.
- **Data Source Triangulation:** this was adopted through the integration of diverse data sources, such as in-depth interviews with various stakeholders such as Employees, Employer Affiliation Bodies, Labour Union representatives and Training Providers. This approach was employed to gain a comprehensive understanding of the research topic, ensuring a more robust analysis of the findings.

2.6 Ensuring Validity and Reliability

In order to maintain the accuracy and credibility of the Project, ensuring the validity and reliability of research findings is key. Validity relates to the extent to which the research method is accurate in measuring the intended variable, whilst reliability relates to the extent to which a research method consistently produces the same outcome if presented to the same sample multiple times (Surucu & Maslakci, 2020).

The following measures were adopted to facilitate the validity and reliability for the study:

- Clearly defining the research question and hypothesis to ensure that appropriate target respondents were selected;
- Appropriate data collection methods and instruments were selected, which included surveys, in-depth interviews, and focus groups, to facilitate the collection of both qualitative and quantitative data from participants;
- Using appropriate and robust statistical techniques such as Advanced Microsoft Excel to conduct qualitative and quantitative data analysis;
- Through the analysis, results were interpreted and reported accurately and transparently in the findings Report. Quantitative results were illustrated in the form of graphs, while qualitative results were incorporated as extracts into the report;
- Adopting mitigating strategies in an attempt to overcome limitations, when limitations were identified, where possible.

2.7 Ethical Considerations

Four key ethical considerations were employed for the purpose of this Project, namely:

- Quality of resources;
- Standards;
- Research Policy; and
- Employee Policies and Practices.

2.7.1 Quality of Resources

As demonstrated in the project execution plan' (i.e., inception report') resourcing section, the Redflank team tasked with delivering this Project had significant experience and are equipped with a wide range of degrees and postgraduate qualifications in fields like engineering, business science, and economics. The team further brought quantitative and qualitative research expertise to ensure a comprehensive analysis of the research topic.

2.7.2 Standards

The Redflank team consistently adhered to the Code of Conduct outlined by the Market Research Society ("MRS"). This code provides standards that encompass all stages of research, from inception and design to execution and use, and was applicable to market, social, and opinion research. The principles of the MRS Code, followed by the team, included:

- Commitments to honesty in professional relationships;
- Transparency in data collection purposes;
- Respect for the rights and well-being of individuals;
- Prevention of harm to respondents;
- A balance between individual needs and professional activities;
- Independent professional judgment;
- Ensuring appropriately trained personnel conducted activities; and
- Safeguarding the reputation and integrity of the profession.

Furthermore, the MRS outlines regulations/standards for the administering of survey incentives, which the Redflank researchers adhered to when offering incentives to participants. These regulations included ensuring that incentives used to encourage participation are proportionate and not perceived as bribes. When offering incentives, participants were clearly and explicitly informed about the administrator, the nature of the incentive, and any related conditions. The Redflank team ensured that incentives did not require participants to spend money, except for permissible monetary vouchers. Additionally, client goods, services, or vouchers for client goods or services were not used as incentives for this Projects. Participants were not promised gifts of client goods or branded materials. The team took measures to prevent the misuse of incentive administration for collecting personal details for unrelated purposes and maintained confidentiality when incentives were offered. .

2.7.3 Research Policy and Practices

Research participants were given the content, sponsorship, and purpose of the research to allow them to make an informed decision about whether they wanted to be

a part of the Project or not. Any assurances, such as confidentiality or anonymity, were also kept. The limitations and shortcomings of the research were disclosed to the MQA and the research team avoided the use of methods that deliberately introduced bias into the results. Survey, interview and focus group questionnaires, including the exact wording and sequencing of questions used in the Project, description of the population and how a sample was selected, sample sizes, and the method, place and dates of data collection, were also submitted to the MQA.

The following practices were adopted to ensure anonymity, confidentiality, and informed consent from participants:

- **Anonymity**

Respondents were informed that their responses and personal information would not be shared with the MQA.

- **Confidentiality**

Data collected from all survey tools/platforms (such as Survey Monkey) was kept confidential and no data or form of data was shared with any person/entity not authorised to view it.

- **Informed Consent**

All of the relevant information was provided on the first 'page' of the survey or in the email containing the link to the survey. This followed the pattern of a paper-based information sheet and covered the identity of the researcher(s), contact details, the reason for conducting the survey and what participant input would be used for. Participants were given the option to provide consent to participate at the start of the survey. For those individuals that did not provide consent, the survey ended immediately.

- **Right to Withdrawal**

Respondents had the option to exit the survey at all times. However, the responses already submitted could not be withdrawn at the point of exit.

2.8 Research Limitations

Two limitations hampered the research process. The table below lists these limitations, and outlines the approach taken by Redflank to overcome said limitations.

Table 2-6: Research Limitations

	Data Collection Limitations	Response to Challenge
1	**Invalid/Outdated Stakeholder Contact Details** The databases containing stakeholder contact details had invalid and/or outdated email addresses and phone numbers, resulting in unsuccessful attempts to contact some stakeholders. This challenge may be attributed to contact details such as email addresses and cell phone numbers being deactivated after some time, for instance if an individual had exited a specific organisation or if their contact details had changed.	• Where a stakeholder could not be reached for an interview due to invalid contact details, they were replaced with another contact from the database.
2	**Stakeholder Unavailability** Several stakeholders did not honour appointments to participate in interviews, despite agreeing to participate in interviews telephonically or via email correspondence.	• In instances whereby stakeholders did not honour appointments, appointments were rescheduled at the convenience of stakeholders.

3 Theoretical Framework

This section outlines the theoretical framework adopted for this Project by defining the key theoretical paradigms that underpinned the research. This framework served as a blueprint that guided the research design process and provided a lens through which research results could be understood. The key theories that framed this study were Diffusion of Innovation Theory ("DOIT") and Grounded Theory. Each theory is outlined below.

Diffusion of Innovation Theory ("DOIT")

DOIT is a framework commonly applied when conducting research focused on technology adoption. DOIT is focused on explaining how and why new innovations (i.e., technologies, products, or practices) spread through a social system over time and is particularly relevant when attempting to understand the level of adoption and acceptance of innovations within a specific population (Boston University, 2022). The concept of diffusion, i.e., the ways in which information regarding an innovation is spread through certain channels over time by the members of a social system, is central to DOIT. Diffusion is influenced by certain factors such as communication channels12, time13, and social system14 characteristics (Minishi-Majanja & Kiplang'at, 2005). Within the context of this Project, the use of DOIT provided a framework to understand technology adoption patterns and allowed for the determination of the current level of technology adoption within different segments of the MMS employer population.

To this end, it is important to note that DOIT is premised on the idea that the adoption of an innovation does not occur simultaneously across the entire social system. Rather, it is a process whereby certain individuals are more willing to embrace the innovation than others (Boston University, 2022). DOIT identifies five adopter categories which segment individuals within a specific social system into five groups, based on their likelihood to adopt the innovation. These adopter groups are listed below (Boston University, 2022):

Adopter Group	Description	Contextual Example
Innovators	Individuals within a social system that eagerly embrace new	Mining engineers or mining technicians at the forefront of

[12] The means through which messages about innovations are transmitted amongst members of a social system. Communication channels are important because information about the innovation must be disseminated to introduce the innovation, change attitudes towards the innovation, and influence decisions relating to the innovation (Minishi-Majanja & Kiplang'at, 2005).

[13] Refers to the time of diffusion and is focused on three dimensions namely (a) the decision-making process, (b) the individual's level of innovativeness and (c) the rate of adoption. The decision-making process considers the time involved between the introduction of the innovation and the decision to accept/reject the innovation. The individuals' level of innovativeness considers the degree to which individuals within the social system accept/reject an innovation. The rate of adoption refers to the speed in which a new idea is adopted (Minishi-Majanja & Kiplang'at, 2005).

14 A social system can be defined as a set of interrelated units such as individuals, groups, and organisations that are engaged in activities associated with a common goal.

Adopter Group	Description	Contextual Example
	innovations. These individuals often serve as 'champions' of innovation.	technological advancements within a specific sub-sector.
Early Adopters	Individuals who follow the innovators and who are opinion leaders. These individuals are typically found within leadership roles, and often embrace opportunities to innovate. These individuals play a critical role in influencing other members of the social system to acquire and integrate new innovations.	Mining supervisors or specialists responsible for implementing new technologies within specific operations.
Early Majority	Individuals who adopt innovations before the 'average person'. These individuals need to see evidence of the effectiveness of a particular innovation before they consider whether to adopt it.	Machine operators or maintenance staff adapting to the use of new equipment.
Late Majority	Individuals who, while initially sceptical of the adoption of innovations, eventually adopt the innovation due to widespread use of the innovation or due to peer influence.	Administrative staff or individuals in support roles who adopt the innovation because of widespread use.
Laggards	Individuals who are least likely to adopt innovations within the social system. These individuals often resist change, which poses challenges to the overall integration and adoption of innovations within a particular social system.	Traditionalists within the MMS, who view technology as more of a threat than an opportunity.

In addition to providing adopter categories, DOIT also provides factors that influence the adoption of an innovation. These factors are listed below (Boston University, 2022):

Factor	Description	Contextual Example
Relative Advantage	The notion that the greater the perceived benefits associated with a particular innovation, the more it will be adopted within a social system.	For example, if a particular piece of equipment shows benefits as it pertains to increasing efficiency, improving safety, and optimising the use of resources, the piece of equipment is more likely to be adopted within the MMS.
Compatibility	Considerations around how compatible the innovation is with the values, experiences, and needs of potential adopters.	For example, the extent to which a particular type of new technology fits in with established workflows within an organisation.
Complexity	The level of complexity associated with acquiring and applying innovations impacts the rate of adoption.	For example, the easier it is to acquire and integrate a piece of equipment within a mining operation, the more likely it is to be adopted across the whole sector.
Trialability	The extent to which a particular innovation can be tested or 'trialled' before a commitment to adoption is made.	The ability to test a piece of equipment before it is integrated into a mining operation is key to mitigating resistance and encouraging broader adoption.
Observability	The extent to which the innovation provides tangible, positive results.	For example, if employees are aware of positive outcomes associated with new equipment, the rate of adoption may be higher.

While the application of the principles of the DOIT framework proved critical to the achievement of the overall aims of the research and provided key insights on the current level of adoption of technology within the MMS, it was important that a comprehensive research study was conducted to ensure robust findings. To this end, the Grounded Theory framework was also used as a key theoretical paradigm, as it provided a guideline for the analysis of emergent themes from empirical research in a structured and nuanced manner.

Grounded Theory

Grounded Theory is a framework that enables the generation of theory that is 'grounded' in data that has been systematically collected and analysed (Noble & Mitchell, 2016). It is essentially focused on constructing theories from multiple data sources which have been systematically obtained and analysed using comparative analysis (Birks & Mills, 2015). Grounded Theory provides researchers with a set of tools that enable a structured approach to sorting through data that allows researchers to determine key theories or insights emerging from empirical research (Thornberg, Perhamus, & Charmaz, 2015). For this Project, Grounded Theory was a key framework that guided data analysis, as it provided a structured approach which allowed for the determination of key theories relating to skills demand and supply within the MMS, sourced directly from the insights of key MMS stakeholders. The framework provided by Grounded Theory prescribes how the theory should be applied in practice. Application of the GT framework in this Project involved the following processes:

- **Initial coding**: Grounded Theory encourages the process of initial coding, which is the first step in data analysis when conducting a study through the lens of the framework. Initial coding is a method used to identify important concepts in the data and label these concepts accordingly (i.e., codes) (Thornberg, Perhamus, & Charmaz, 2015). Initial coding is often followed by focused and theoretical coding, which involves refining the codes developed initially (Birks & Mills, 2015). Within the context of this Project, a detailed examination of interview and focus group transcripts was conducted to identify initial themes and to formulate initial codes. Further coding analysis was conducted to formulate clearly defined themes (using constant comparative analysis techniques, as outlined below).
- **Concurrent data collection and analysis:** One of the key principles of Grounded Theory is collecting data with an initially purposive sample (Birks & Mills, 2015). The data from these initial consultations are coded before more data is collected. For this Project, initial consultations were conducted with several employers within the MMS as well as representatives from the CSIR, SATCAP and MCSA to help provide initial insights that helped to frame the data collection instruments, which provided a foundation for more comprehensive data collection to occur.
- **Theoretical sampling:** conducting research through the lens of Grounded Theory lends itself to adopting theoretical sampling when selecting participants for the study (Birks & Mills, 2015). This means that study participants are chosen based on theoretical considerations emerging during the research process. To sample theoretically, the researcher must make strategic decisions regarding the study participants, with due consideration given to those individuals that will provide the most insightful information (Thornberg, Perhamus, & Charmaz, 2015). For this Project, careful consideration was given to the individuals who formed part of interviews, with participants being selected according to specific criteria, including organisation size, the position of the individual being interviewed, as well as the location of the organisation.

- **Constant comparative analysis:** a key part of applying Grounded Theory principles in a practical setting is comparative analysis of different data sources throughout the data collection process to continuously refine categories/themes (Birks & Mills, 2015). For this Project, constant comparative analyses were conducted throughout the data collection process and involved the comparison of diverse data sources including survey, interview, and focus group data.
- **Saturation:** Grounded Theory is concerned, at a fundamental level, with obtaining a level of data saturation. Saturation is reached when new data gathered through the research process fails to provide new insights (Noble & Mitchell, 2016).
- **Emergent theory**: the final product of Grounded Theory is an integrated and comprehensive theory that explains a particular phenomenon (Birks & Mills, 2015). This final process is concerned with building theories from the data collected as part of the research, using the techniques and practices listed above.

The rationale for the adoption of the DOIT and Grounded Theory frameworks as key theoretical reference points for this Project was because of the nature of the research topic at hand. For this Project, DOIT served as the overarching framework, guiding the process of determining the current level of adoption of technology within the MMS and associated challenges with technology adoption. This helped, from a conceptual perspective, to categorise respondents into different adopter categories and to determine factors influencing the level of technology adoption, which was critical to framing the insights contained within this Report. Concurrently, the framework prescribed by Grounded Theory was applied to allow for a comprehensive and nuanced exploration of specific themes and patterns relating to skills demand and supply within the MMS such as, for example, identification of specific skills gaps within specific sub-sectors, or providing insights into the reasons underpinning limited adoption of technology within organisations of a specific size.

4 Literature Review

The section below provides key insights from the desktop research undertaken. Consulting desk-based sources was a critical step in formulating a conceptual foundation for the Project.

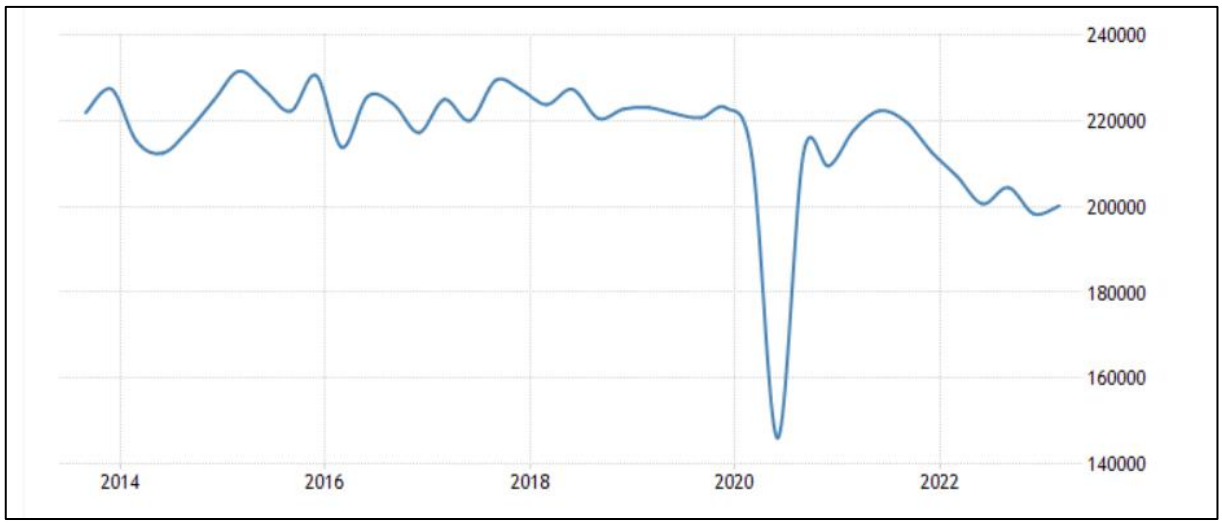
4.1 Overview of the MMS

Mining involves the extraction and transformation of precious metals and minerals, as well as other geological materials (Corporate Finance Institute, 2022). Mining Companies can be categorised into artisanal and small-scale mining ("ASM") and large-scale mining ("LSM"). Artisanal mining involves individuals using rudimentary methods and tools to access mineral ore, usually for subsistence, while small scale mining is conducted by smaller producers sanctioned by authorities with limited capital (Debrah, et al., 2014). In contrast, LSM focuses on accessing large high-grade mineral deposits, which are typically economically feasible for large companies (Rodríguez-Novoa & Holley, 2023). The South African MMS encompasses nine sub-sectors, each contributing to the extraction and processing of valuable resources, namely: gold mining, coal mining, PGM mining, CLAS mining, other mining; diamond mining; diamond processing, jewellery manufacturing; and services incidental to mining.

4.2 Economic Performance

The South African MMS is a key contributor to the South African economy. Currently, the mining sector contributes approximately R202.61 billion of the South African Gross Domestic Product ("GDP") and provides direct employment to roughly half a million people (MQA, 2021). However, despite its importance to the South African economy, statistics indicate that between 2014 and 2022 the sector has been in decline in terms of contribution to the South African GDP. This can be seen in the figure below.

Figure 4-1: Mining Contribution to South African GDP



Source: Trading Economics (2023)

The contributions made to the South African GDP dropped to R202.61 billion in 2022 from R218.12 billion in 2021. Research by Statistics South Africa (2022) cites the

steady decline in the productivity of the South African mining and minerals sector as a key contributing factor to the decline in contributions made to GDP. According to McKinsey's 'Mine Lens Productivity Index', which tracks over 240 mining operations globally, the productivity of South African mining operations in base metals, iron ore and platinum declined by 0.3% a year between 2013 and 2017 (McKinsey & Company, 2019). This productivity stabilised between 2017 and 2018 but continued to decline in 2019, dropping by 2.8% (African Development Bank Group, 2021). Contrastingly, the mining sectors in Asia, North America and the Oceania regions improved their productivity by more than 5% a year between 2013 and 2018 (Mckinsey & Company, 2020). Research by McKinsey & Company further found that due to the COVID-19 pandemic, in 2020 global mining operations experienced a decline of roughly 42% (Mckinsey & Company, 2020). This significant decline in the productivity of mining operations globally illustrates the significant impact that COVID-19 had on mining economic performance as well as the mining sector.

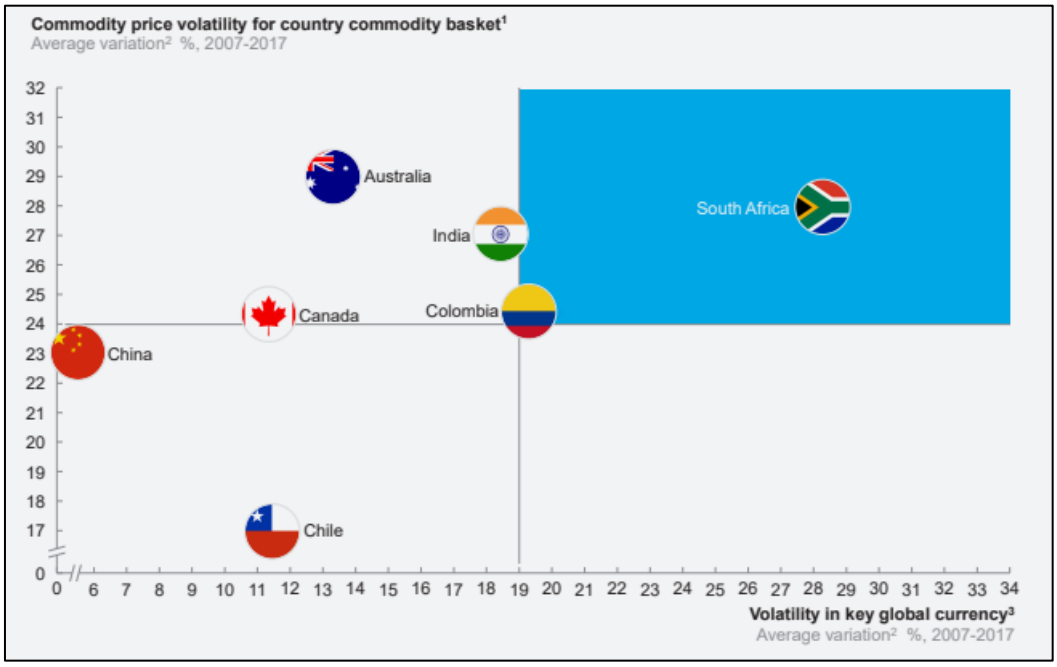
Beyond COVID-19, a key contributor to the decline in productivity is the lack of operational and cost competitiveness of many mining organisations within the South African MMS. This is reflective of the fact that many of South Africa's mines are aging, with deposits being at greater depths and the quality of ore deposits declining (McKinsey & Company, 2019). This is a concern because declining ore grades at current depths means that mining operations must expend more resources to reach new deposits at greater depths, which increases the cost of extracting these deposits. Mining at these depths also has implications in terms of safety, given the higher risk of rockfalls, flooding, gas discharges, seismic events, and ventilation problems (Lane, et al., 2015).

The Minerals Council of South Africa ("the Minerals Council") recognises the challenges facing the South African MMS, noting that, despite South Africa being recognised as a global leader in deep-level mining, the methods used to extract minerals in these deep level mines have remained largely unchanged since the early 1900s. These methods include drilling, blasting, and cleaning (Minerals Council, 2019). Given that technology has rapidly developed since the early 1900s, the Minerals Council further notes that the methods traditionally used for mineral extraction in South Africa are unsustainable. In addition to posing health and safety challenges, these methods do not promote productivity and often come at high costs. Furthermore, within the next decade, as traditional methods fall short of accessing mineral resources at depth, mines may be forced to close. This inevitably has an impact on employees who may be left without an income due to mine closures. Considering that, on average, every miner supports 10 family members, this could potentially impact around two million people in South Africa (Minerals Council, 2019).

Another challenge that impacts the South African MMS' ability to contribute to GDP is extreme vulnerability to volatility – including both price volatility of the major metals in South Africa's commodity basket and currency (Minerals Council South Africa, 2021). In fact, research indicates that South Africa has the currency with the highest volatility

and a basket of metals (including chrome, coal, copper, iron ore, lead, manganese, diamonds, gold, platinum, and cobalt) with one of the highest levels of price volatility, as seen in the figure below.

Figure 4-2: Currency and Commodity Price Volatility of South Africa Compared to Other Mining Countries



Source: McKinsey & Company (2019)

Furthermore, the South African MMS has faced several infrastructure challenges which have impeded the sector's growth over the past decade. One example of this is the challenge associated with load shedding, and the consequent increased costs of electricity in South Africa. Research shows that, between 2007 and 2022, electricity costs have increased by 653%, whilst inflation over this period was 129%, meaning that electricity prices have quadrupled in real money terms (Moolman, 2022). These rising electricity costs negatively impact mining organisations as operational costs are increased due to an increase in the Eskom tariffs which may result in a decrease in profit margins. These high electricity prices may also play a role in minimising profits as these operational expenses result in mining organisations increasing the prices of minerals. An increase in the price of minerals make it harder to sell to the global market, due to the competitiveness of the market.

Other challenges cited in the literature include the capacity constraints and derailments in the South African rail network which has significantly hampered exports of bulk commodities such as iron ore (McKinsey & Company, 2019). Research indicates that South Africa's ability to export bulk commodities were severely impacted by rail network deficiencies, with a decline of approximately 40% in the minerals volume exported by the mining sector in 2022 – resulting in a loss of R50 billion in exports (Burger, 2023). The challenges with rail infrastructure also impacts the growth of the mining sector in South Africa, particularly due to its impact on junior, exploration and

emerging miners ("JEEMs"), which are recognised as being fundamental to the future of mining in South Africa (Burger, 2023). Research indicates that several emerging mining organisations within the coal sub-sector, who were reliant on exporting coal to generate revenue, were severely impacted by the lack of rail logistics capacity in 2022 (Burger, 2023). Many of these organisations had to resort to utilising road transportation to move processed coal, which impacted their profit margins given the higher cost of road transportation.

Furthermore, due to the uncertainty around rail logistics capacity, many organisations resorted to reducing the amount of coal produced to avoid stockpiling large amounts of coal, which further impacted their turnover and profitability (Burger, 2023). Similar trends were noted for emerging mining organisations within the chrome sub-sector, with research showing that only 4.5 million tonnes of chrome were transported by rail in 2022, despite the sub-sector being allocated 8.6 tonnes of capacity on rail corridors for the year (Mining Weekly, 2023). Several organisations within the chrome sub-sector also resorted to using road transportation to move their product, which had similar implications on their profit margins given the higher cost of transporting products via road networks.

4.3 Changing Technology within the MMS

Considering the changing technology within the global mining sector, it is important to understand how the skills required for specific occupations may change due to the use of more sophisticated technology. However, to understand the implications that changing technology may have on skills, it is critical to first understand how changing technology can impact the specific activities conducted within the MMS value chain.

In the current context, the advent of the Fourth Industrial Revolution ("4IR") has ushered in a new era within which mining processes and activities are conducted in South Africa. Within the MMS, the application of technology is increasingly focused on areas where it can yield significant measurable benefits (CSIR, 2023). This encompasses the implementation of new technologies such as AI, automation, and big data in the production processes throughout the mineral extraction value chain, enabling mining companies to enhance productivity and to mitigate against escalating operating costs (Mungadze, 2021). For instance, AI-powered drilling systems utilise real-time data relating to the drilling environment to optimise drilling parameters such as speed, direction, and depth. This results in improved accuracy, efficiency, waste reduction, and enhanced recovery rates during the extraction phase of the mining value chain (D'Almeida, et al., 2022).

Other 4IR related technologies, such as drone technology, can be employed during the exploration phase for conducting reconnaissance studies, significantly reducing surveying time. In addition to the use of drone technology, research indicates that several breakthrough technologies[15] and/or methods are being used to improve the

[15] These breakthrough technologies may necessitate the upskilling of mining geologists, particularly as it pertains to the use of these technologies to increase efficiencies and reduce costs at the exploration phase.

efficiency of the activities conducted within the exploration phase (Okada, 2022). Some of these technologies include induced polarization, airborne electromagnetics, airborne gravity gradiometry, spectroscopic methods, global navigation satellite systems, unmanned surveying platforms and neural networks/deep learning. These innovations may serve to increase economic efficiency (e.g., reduced labour costs due to increased use of automated or unmanned equipment), may ensure higher work efficiency and may result in lower implementation costs (Okada, 2022).

Moreover, the utilisation of AI enables enhanced monitoring of critical mining assets by integrating specific assets, such as haulage trucks, with Internet of Things[16] ("IoT") sensors. These sensors are responsible for tracking various factors such as vibration, motion, haul vehicle movement for mineral transportation, as well as oil temperature and pressure levels in trucks. The data collected from these sensors can be stored and processed using cloud computing, which facilitates data sharing and integration (Mining Technology, 2021). By analysing the gathered data, predictive maintenance can be performed on equipment like conveyor belts, which may be used for transporting mineral ores from mines to the surface, allowing for timely repairs before any failures occur. The ability to conduct real-time operational analysis therefore can promote efficient equipment usage and reduce accidents in mining operations (Job, 2021). Moreover, digital tools have the capability to provide real-time data and analytics on other aspects of mining operations, including ore quality during exploration, equipment performance in the extraction and processing stages, and energy consumption across the entire mining value chain (McKinsey & Company, 2015).

The MMS is also adopting other emerging technologies including robotics, 3D printing, and machine learning. These advancements contribute to enhancing the sector's global competitiveness in terms of cost-efficiency and addressing environmental, social, and governance concerns (Mungadze, 2021). Although the implementation of robotics in the MMS is currently limited, it presents numerous potential opportunities. For instance, a robot could be employed to automatically replace idlers in the mineral hauling process on operational conveyor belts. This has the potential to improve conveyor maintenance, which currently poses challenges to mineral extraction efficiency due to its difficulty, risk, and the need to halt belt operations, challenges which impact on efficient production (Rungasammy & Nembudani, 2021).

In addition to the points mentioned above, the implementation of technology such as remote monitoring, data analytics, cloud computing, and AI can assist mines in optimising their operations, enhancing safety and reducing costs by improving productivity and efficiency through a decrease in manual labour (Walker, et al., 2020). Furthermore, the utilisation of smart protective devices such as smart helmets and safety glasses, which can be connected to devices like cell phones and watches, can contribute to heightened worker safety during the extraction of minerals (MQA, 2023).

[16] The Internet of Thing refers to a network of physical objects or 'things' that are embedded with sensors, software and other technologies for the purposes of connecting and exchanging data with other devices and systems using the internet.

Regarding the current technological innovations being implemented by South African stakeholders, some of the local mining operations and/or bodies introducing and implementing breakthrough technologies include Rio Tinto, Sibanye Stillwater, Baletsema Mining Services, and CSIR as outlined below (Wadula, 2022):

- **Rio Tinto** – Rio Tinto is a leading proprietor and operator of Autonomous Haulage Systems ("AHS") globally. These haulage trucks can operate continuously except for scheduled maintenance and refuelling, with no pause for employee breaks and shift changes (Wadula, 2022). The trucks are equipped with wireless connectivity capabilities, global positioning systems ("GPSs"), autonomous controls and obstacle detection systems, enabling route mapping and navigation for the trucks (Telematics, 2023). These trucks are deployed as part of the transportation sub-component of the mineral extraction value chain. The use of AHSs has led to enhanced worker safety through the avoidance of potential hazards and risks associated with operating heavy equipment, such as fatigue, exposure to noise and dust or soft tissue and joint problems such as tendinitis (Wadula, 2022).
- **Sibanye-Stillwater** – Sibanye Stillwater is affiliated with the DigiMine initiative, an advanced mining laboratory that employs cutting-edge digital technologies to enhance safety and sustainability in mining operations (Wadula, 2022). The DigiMine laboratory includes a mock mine that allows simulation of actual underground mining conditions, thus enabling researchers to develop and test digital systems to design the mine of the future (Sibanye Stillwater, 2023). The technologies enable control systems within mines to autonomously observe and evaluate health and safety risks to miners during mining activity and take remedial action where necessary, including moving towards real-time responses (Majozi, 2022). The goal of the DigiMine initiative is to use technology to mitigate the risks typically associated with mining activities, providing mine workers with greater protection (Wadula, 2022).
- **Baletsema Mining** – Baletsema Mining is a consulting firm offering a diverse range of technical, operational, and business improvement solutions and products to the mining sector, including AI coupled closed-circuit television ("CCTV") cameras, proximity detection software, and mining optimisation software and programmes. The company is devoted to the technological advancement of mining and recognises the significance of 4IR in revolutionising the South African mining industry.
- **CSIR –** CSIR has introduced mine safety technology innovation called Goafwarn. Goafing is the term used to describe the occurrence of ground collapses in underground coal mines, which can result in severe economic and safety consequences for mining operations. To mitigate the risks associated with unplanned or unexpected goafs, the CSIR has created an innovative solution that incorporates embedded electronics and sensors in a device that can be installed in underground mines, adjacent to an exposed surface of coal

in the mine, monitoring mine walls for expected goafing and thus improving safety and efficiency in the mining industry (Isaac, 2023).

By integrating breakthrough technologies, mining organisations can improve their efficiency in processes such as locating minerals for extraction, extracting the minerals, as well as processing ore deposits. The implementation of breakthrough technologies may, thus, enhance the global competitiveness of the South African mining industry, attract top talent, and ultimately increase the MMS's contribution to the economy and society (Wadula, 2022). However, to reap the benefits associated with integrating breakthrough technology across into mining operations, it is important to note the current skills gaps that are existent within the South African MMS, as well as the current level of demand within the MMS for certain skills.

Understanding skills demand and supply dynamics are critical for the MMS, and for the MQA, particularly because understanding said dynamics are crucial to workforce planning and policy formulation processes. As such, one of the key research objectives of this Project was to understand the current level of demand and skills supply considering the changing technology within the sector. While the literature provided contextual insights on skills demand and supply within the MMS, there was an urgent need for the MQA to understand how changing technology may impact on skills requirements and occupations within the MMS in the short-term future (i.e., 1 to 2 years). Insights relating to the current level of demand and skills supply are detailed in Section 8 of this report.

Understanding skills demand and supply dynamics are critical for the MMS, and for the MQA, particularly because understanding said dynamics are crucial to workforce planning and policy formulation processes. As such, one of the key research objectives of this Project was to understand the current level of demand and skills supply considering the changing technology within the sector. While the literature provided contextual insights on skills demand and supply within the MMS, there was an urgent need for the MQA to understand how changing technology may impact on skills requirements and occupations within the MMS in the short-term future (i.e., 1 to 2 years). Insights relating to the current level of demand and skills supply are detailed in Section 8 of this report.

4.4 Threats of Changing Technology

While there are numerous potential benefits associated with the implementation of more sophisticated technologies within the South African MMS, as outlined above, it is important to note that introducing said technologies into mining operations represents both an opportunity and a threat. Some of the identified threats include potential job losses due to automation, as well as an unskilled work force. These considerations are discussed in the sections that follow.

4.4.1 Workforce Challenges

The first consideration for organisations within the MMS looking to implement more sophisticated technologies is the impact that enhanced digitisation may have on the

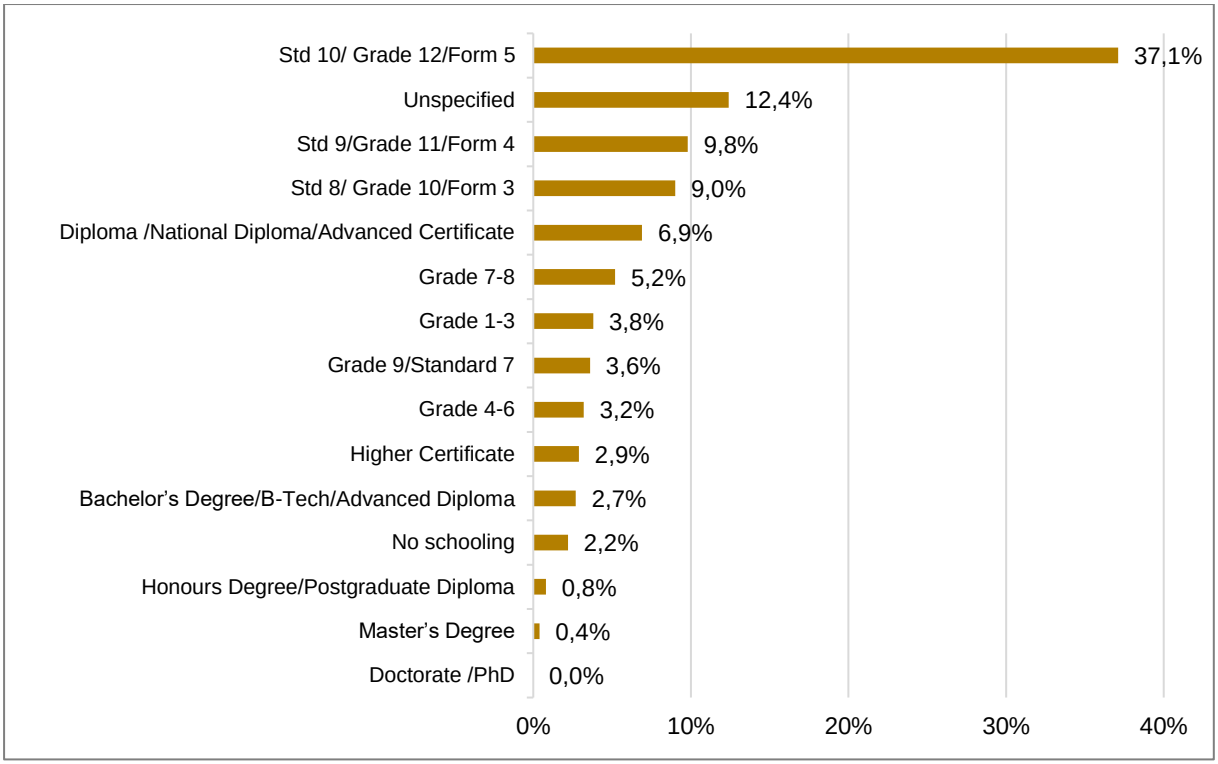
MMS workforce. Implementation of more sophisticated technologies is anticipated to have a significant impact on the MMS workforce, both in terms of employment as well as skills development. For instance, the use of technologies such as automation and robotics can lead to job losses if repetitive and manual tasks become automated. Consequently, the employees that perform these tasks will either need to be reskilled or upskilled to transition into other occupational roles or face unemployment. The challenge of reskilling and/or upskilling the MMS workforce is further highlighted by the fact that digital transformation in mining will require creating new occupational roles that may either require traditional mining skills to be supplemented or may not require traditional mining skills at all (PwC, 2023).

The impact that changing technology may have on the MMS workforce is therefore considered to be a major concern, with sector experts agreeing that the implementation of 4IR technology will greatly impact labour dynamics within the sub-sectors (Zulu, et al., 2021). This has been echoed by labour unions within the MMS, who have raised concerns that the introduction and implementation of new technology may accelerate job losses (Maswanganyi, 2021). As a result of these concerns, and considering the fact that organisations within the MMS have a complicated relationship with trade unions within the sector, there is a risk that if the implementation of more sophisticated technologies is not managed carefully, it could potentially heighten tensions between organisations and the MMS workforce (Maswanganyi, 2021).

Research indicates that the implementation of new technologies could result in the displacement of approximately 3.3 million existing jobs by 2030 (McKinsey & Company, 2019). However, in noting these displacements, it may also be noted that the introduction of new technologies has the potential to create up to 4.5 million new jobs across all economic sectors, which represents a net gain of 1.2 million jobs (McKinsey & Company, 2019). These projections suggest that short term job losses as a result of 4IR technology implementation will be offset by the long-term employment created by the introduction of more sophisticated technologies.

The challenge regarding potential job losses is compounded when considering the traditional nature of the MMS workforce – with the sector being characterised by workers with low literacy levels and a lack of familiarity with digital tools such as computers and other electronic devices (PWC, 2021). The figure below illustrates the educational levels of MMS employees.

Figure 4-3: Employee Educational Level in the MMS



Source: MQA (2022)

As can be seen, the majority (37.1%) of employees have a Grade 12 level of education, while only 2.7% of MMS employees have a bachelor's degree or advanced diploma. Furthermore, approximately 7% of MMS employees have a foundation and intermediate level of education (i.e., Grades 1 – 6), while 2.2% have no formal schooling at all. These results are consistent with the view from organisations within the MMS, with less than a third of organisations within the sector[17] being of the view that their employees have the necessary skills to realise the company's vision of the digital future (PWC, 2021). Approximately 95% of the new occupations that are expected to emerge within the mining sector are expected to be for skilled workers.[18] Proficiency in the use of high impact technology, as well as workers with a combination of technical and soft skills are required in the sector, considering that the successful adoption of 4IR technologies typically requires a workforce with digital skills. Therefore, the extent of upskilling and reskilling that is required to ensure that the current MMS workforce is equipped with the relevant skills is evident. Further literature supports this notion, with Stanz, et al., (2021) noting that the transition to modernisation will require extensive re-training of mine employees and the acquisition of new skills. Furthermore, as a result of modernisation, the MMS may require more engineers, information technology ("IT") specialists and maintenance artisans. Projections indicate that over 1.7 million jobs will be created for individuals who have completed technology related studies as part of their higher education by 2030 (Stanz, et al., 2021). The lower literacy

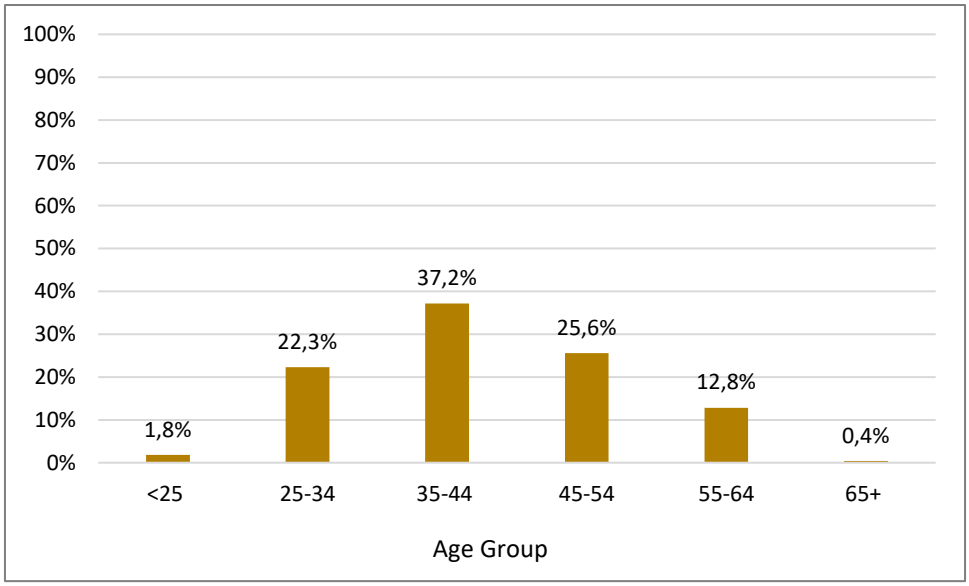
[17] Based on a sample of 23 senior managers and executives across 19 South African mining companies.

[18] PwC (2021).

and education levels of the current MMS workforce, therefore, poses a challenge regarding the ability to reskill workers.

In addition to the above, another potential challenge to 4IR technology implementation as it pertains to the MMS workforce is the age of employees within the sector. The following graph provides a breakdown of the age of MMS employees.

Figure 4-4: Employee Age Distribution in the MMS



Source: MQA (2022)

As can be seen, the majority (37,2%) of MMS employees fall within the 35-44 age group while 38,8% of the employees in the sector are over the age of 45. Only 1.8% of the current MMS workforce is under the age of 25, which is perhaps indicative that there is a limited number of younger people entering the MMS workforce. According to the literature, young people are traditionally not attracted to the mining sector with young graduates preferring to live in cities as opposed to smaller mining towns (Stanz, et al., 2021). This is important to note because research indicates that while the aging MMS workforce may have deep sector knowledge, these individuals may struggle to work with digital tools once mechanised mines become more prevalent (Maswanganyi, 2021).

Furthermore, research indicates that mindset, culture, and behaviour is a key contributor to the successful implementation of innovative technologies (Maswanganyi, 2021). In essence, employees must have the willingness to adapt to change. Maswanganyi (2021) notes that MMS employees tend to possess 'traditional' attitudes towards change and are embedded in a culture of unwillingness to familiarise themselves with new and innovative technologies which may serve to be a barrier to 4IR technology implementation. This is exacerbated by the age profile of MMS employees, with research further indicating that older employees tend to face challenges with utilising innovative technologies due to technical and attitudinal barriers (Yang, 2019).

The broader mining sector is also often viewed as conservative and resistant to change, with obstacles to innovation including remote work locations, as well as a perceived impractical and inefficient approach to the development, implementation, and commercialisation of new technologies by the sector (Ediriweera & Wiewiora, 2021).

4.4.2 Organisational, Infrastructure and Institutional Challenges

In addition to the challenges associated with the MMS workforce; there are specific organisational, infrastructure, and institutional challenges impacting the implementation of more sophisticated technologies. According to Zulu, et al. (2021), organisations face several challenges in the implementation of 4IR technologies such as a lack of impetus to implement more sophisticated technologies, challenges related to infrastructure constraints and institutional setups. Certain organisational barriers also impact on new technology implementation, such as insufficient funding, the limitations of existing IT systems, unclear roles and responsibilities for mining employees, a lack of vision, an unclear business case, as well as instances of different business units within mining organisations operating in siloes (Zulu, et al., 2021).

The use of more sophisticated technologies may also result in increased cyber risk for organisations attempting to integrate said technologies into current operations. This is mainly because these technologies are dependent on the flow of data via a network connected to the internet, which is susceptible to various threats (Maswanganyi, 2021). Given that ‘big data’ databases typically contain large amounts of data, any breach of this data poses significant risks, and may result in a leak of confidential information regarding a particular mines’ performance. Maswanganyi (2021) notes that, due to a lack of experience regarding the use of digital systems in the MMS, the extent of the potential cyber threats and the associated consequences is unknown. Furthermore, organisations within the MMS are still uncertain regarding the level of protection, as well as the expertise required, to guard against potential cyber threats (Maswanganyi, 2021).

The threats identified through desk-based research were explored further through fieldwork. This proved to be useful in terms of understanding the current perceptions of employers within the MMS as it pertains to the manner in which the introduction of more sophisticated technologies within mining operations may impact the MMS workforce, as well as the barriers that are limiting the increased uptake of said technologies. These insights are documented in Section 8.1 of this report.

4.5 Mitigating the Disruptive Impact of Changing Technology

Within the South African MMS, research conducted by MEMSA suggests that successful implementation of 4IR technologies will require a workforce well equipped with technical and soft skills, including skills related to change management and creative thinking around new business models (Ramdass, 2022).

From the perspective of qualifications, research suggests that workers within the MMS may require more process-independent qualifications (i.e. qualifications not limited to specific jobs or sectors, for example, a project management certification, which is often considered process-independent as it provides skills and knowledge that can be valuable and applied across mining operations and occupations) to execute their responsibilities in a modernised mine (Stanz, et al., 2021). Organisations within the sector must therefore consider whether to focus spending on either reskilling and upskilling current employees or finding new employees who are familiar with digital tools.

Furthermore, insight from literature has revealed that, in many instances, organisations typically retrofit existing business structures and systems with 4IR technologies, which is a challenging process that needs to be carefully managed (Zulu, et al., 2021). This was corroborated by research conducted by Maswanganyi (2021), who revealed that the South African MMS has been particularly slow in embracing innovative technologies due to the challenges that are associated with retrofitting new technology to already existing infrastructure. For example, in the gold mining sub-sector, mining operations typically have mature infrastructure and underground working environments that are remote and located at extended distances from mine shafts. Furthermore, underground mining environments are typically dark, humid, and punctuated by seismic events (Maswanganyi, 2021). Organisations looking to implement 4IR technologies must therefore consider these conditions, and need to ensure that the technology that is installed is able to remain functional several kilometres below the Earth's surface and is able to function in challenging underground conditions.

Additionally, an important consideration for the MMS is that an all-encompassing technology platform is required to ensure reliable and accurate data collection, data processing and analytics, data exchange, connection, and coordination, for 4IR technologies to successfully be integrated throughout an organisation's value chain (Zulu, et al., 2021). This requirement leads to other challenges and requires organisations to consider how to create and manage 'big data' and information. Furthermore, from a resourcing perspective, organisations would require individuals with high level data analytics and data management skills, which are generally considered to be scarce in the South African MMS context (Zulu, et al., 2021).

While the literature provided a solid knowledge base regarding the specific skills that may be required by employees within the MMS considering the changing technology within the sector, the fieldwork conducted as part of this Project identified specific MMS sub-sector skills gaps, as well as the specific soft and technical skills that will be in demand in the short-term future. A detailed discussion on MMS skills gaps is included in Section 8.2 of this report.

5 Policy and Legislation

Various policies currently exist that are intended to promote skills development in South Africa. These include the National Development Plan ("NDP") 2030, National Skills Development Plan ("NSDP"), the Human Resource Development ("HRD") Strategy for South Africa and Economic Reconstruction and Recovery Plan Skills Strategy ("ERRS"). The following paragraphs provide further detail regarding these policies.

The NDP, published in 2012 as part of the country's efforts to reduce inequality and eliminate poverty by 2030, serves as a long-term vision and strategic framework for the country's development, outlining goals and targets across various sectors to address socio-economic challenges and promote inclusive growth. The plan emphasises sustainable development, job creation, education, and improved infrastructure to build a more prosperous and equitable nation (South African Government, 2023). Furthermore, the plan places a strong emphasis on the need for innovation in both emerging and established sectors, such as mining. In line with this, the plan aims to improve education, training and innovation through a number of initiatives including; the production of 30 000 artisans per year, increasing the enrolment at universities by 70% by 2030 and improving the throughput rate to 80% by 2030.

In addition to the NDP, the NSDP is a key policy framework that outlines South Africa's approach to skills development. The policy aims to create a highly skilled and competent workforce that will advance both the social and economic growth of the country. The NSDP aims to enable both government and social partners to contribute towards economic growth by enhancing the standard of education and training, increasing access to educational and training opportunities, encouraging innovation and entrepreneurship, and developing skills in growing economic sectors. While not exclusively focused on 4IR-related skills, the NSDP recognises the importance of adapting to technological changes as it seeks to: "Harness the use of technology, where possible and relevant, standardise processes across all skills levy institutions, improve efficiencies and increase stakeholder involvement through online portals and accurate data analysis for improved decision making" (Department of Higher Education and Training, 2019).

The HRD Strategy for South Africa was developed in 2001 as a comprehensive strategy that addresses the development of a country's human capital and sustainable economic growth. The NSDP, Sector Education and Training Authorities (SETAs), and National Qualification Frameworks (NQFs) are some of the tools used to implement the HRD Strategy and encourage the formation of an educated workforce that will contribute to the economic development and growth of the country. While the HRD strategy has been reviewed several times since its introduction, some of the goals of the HRD strategy as defined by the National Integrated Human Resource Development include; strengthening basic education and foundation programmes, expanding access

to quality post-schooling education and training, improving research and technological innovation outcomes and producing appropriately skilled people for the economy.

The ERRS, on the other hand, is a developing strategy which aims to ensure that implementation of the Economic Reconstruction and Recovery Plan ("ERRP") will be supported by skills that are readily available. It recognises that the implementation of the key components as outlined in the ERRP requires certain skills, which include a mix of technical, managerial, and leadership skills across various sectors, and will fail if these skills are not available. The interventions set out in the ERRS include but are not limited to the expansion in the provisioning of short skills programmes and the enablement of the provision of targeted skills programmes which both seek to enable the development and provision of skills training that is responsive to the industry that can be implemented promptly by training providers (Department of Higher Education and Training, 2022).

While the above policies consider ways in which skills development can be supported in the context of changing technology, the South African educational system has not accommodated or kept pace with technological changes (Mendy & Madlope, 2020). This is, in part, as a result of a lack of agility in educational institutions and slow curriculum development and review processes (Moonasamyl & Naidoo, 2022). It has been argued that there is a need for flexible educational programmes, systems, and curricula in order to provide skills for the 4IR and future industrial revolutions (Chetty, 2019). Efforts toward skilling for the future have been stifled by long processes in the development of qualifications and accreditation of training providers through the Quality Council for Trades and Occupations ("QCTO") and the South African Qualifications Authority ("SAQA"). According to the ERRS, stakeholders in the sector have noted the following challenges in relation to the disbursement of the Discretionary Grant (Department of Higher Education and Training, 2022):

- The QCTO qualification development process is drawn out by the dependency on external consultants.
- The demands of SETA processes for accessing the Discretionary Grant and South Africa's education and training quality assurance system have created obstacles for employers and training providers in their efforts to provide accredited and non-accredited skills programmes.
- Accreditation is only granted to Skills Development Providers who offer programs that are linked to qualification pathways. In cases when adequate registered qualifications do not yet exist, such a requirement is ineffective.

In order to ensure that sectors including the MMS respond timeously and adequately to the impact of the 4IR, it is necessary to ensure that skills and qualification accreditation bodies such as the QCTO and SAQA are prompt in accrediting relevant programmes.

5.1.1 Technology Related Policy Frameworks

In addition to the national skills development policies outlined above, there are a number of 4IR and technology-related policy frameworks that have been developed by various government entities and departments. The following table identifies and highlights the various 4IR policies that have been implemented in South Africa in order to aid the implementation of the 4IR in the country overall, as well as within the MMS specifically. Furthermore, an overview of their implementation to-date is provided.

Table 5-1: Technology Focused Policies in South Africa

#	Policy	Description	Effectiveness of Implementation
1	**Presidential Commission on the Fourth Industrial Revolution Strategic Implementation Plan ("PC4IR SIP")**	• The goal of the PC4IR SIP is to ensure that the country can fully participate in and benefit from the 4IR by developing a comprehensive strategy for implementing new technologies and digital advancements in key areas such as education, healthcare, transportation, and infrastructure (Department of Communications and Digital Technologies, 2020). • The plan aims to promote economic growth, create jobs, and improve the standard of living for all citizens by leveraging the opportunities presented by the 4IR (Department of Communications and Digital Technologies, 2020). • Additionally, the plan aims to address the challenges that may arise from the rapid pace of technological change, such as inequality, unemployment, and social dislocation (Department of Communications and Digital Technologies, 2020).	In line with the PC4IR SIP goals, the following has been achieved to-date: • Adoption of the e-government strategy and roadmap to guide digital transformation of public service (Department of Communications and Digital Technologies, 2023). • Launched AI Hubs at the University of Johannesburg and the Tshwane University of Technology with the aim of providing training and creating a positive social impact around the involvement of AI in key sectors of the economy (Department of Communications and Digital Technologies, 2023). • Completion of the high-demand radio frequency spectrum auction which set out to allocate high-demand spectrum bands (e.g., 700MHz, 800MHz, 2 300MHz, 2 600MHz, and 3 500MHz, which are needed for high-speed broadband and 5G) to telecommunications

#	Policy	Description	Effectiveness of Implementation
		• The key recommendations on how to achieve the PC4IR SIP goals include (Department of Communications and Digital Technologies, 2021): ○ Investment in human capital; ○ The establishment of an AI Institute; ○ The establishment of a platform for advanced manufacturing; ○ Securing and availing data to enable innovation; ○ Incentivising future industries, platforms and applications of 4IR technologies; ○ Building 4IR infrastructure; ○ Reviewing and amending (or creating) policy and legislation; ○ Establishment of a 4IR Strategic Implementation Coordination Council Th above recommendations will be implemented through the development of a strategic implementation plan which includes cross-sectorial 4IR programmes and institutional establishments highlighting the potential for the development of 4IR infrastructure within the MMS at a national level.	operators within the country, to ultimately transform and create competition in the telecommunications sector with respect to the reduction of costs to communicate. This initiative aims to improve digital infrastructure and enable the deployment of new technologies in public schools, public clinics and hospitals, and police stations (Department of Communications and Digital Technologies, 2023). While there are no sectorial-specific initiatives that form part of the PC4IR SIP, access to broadband connectivity, improved digital infrastructure and introduction of new technologies for public institutions such as schools as well as the increased focus of research and development in the field of AI will broadly impact the level of skills and knowledge of the 4IR and innovative technologies amongst the population, which may, in turn, facilitate the implementation of the 4IR across various sectors, including the MMS.

#	Policy	Description	Effectiveness of Implementation
2	**Department of Science and Technology ("DST") Ten-Year Innovation Plan**	• The strategy outlines a medium-to-long-term policy direction for the transformation towards a knowledge-based economy, with a focus on where the country should be in ten years (Alexander, 2021) • The policy is driven by four key elements namely, human capital development, knowledge generation and exploitation, knowledge infrastructure and enablers to addressing the innovation gap between research results and socioeconomic outcomes (Alexander, 2021) • The first of the plans, related to science, technology and innovation, was approved in March 2021 (Alexander, 2021)	The DST Ten-Year Innovation plan has developed a number of indicators related to strategic priorities that the plan will focus on. The plan has identified the following as tentative indicators for the mining sector (Department of Science and Innovation, 2023): • Improved mining sector factor productivity • Increased R&D intensity of sector • Improved effectiveness and efficiency in mining sector operations for developing and adapting high-tech applications for sustainability • Increased R&D intensities and competitiveness of the mining sector • Strengthen the integration of key enabling high-technology and mining equipment to improve accuracy and extraction levels • Increased use of high-tech equipment, services and processes in mining to drive the sector's sustainability and competitiveness • Increased use of high-tech to enable mining equipment tracking, usage and proactive failure warning In order to meet the objectives of the mining sector indicators, the Ten-Year Plan envisages modernising mining through

#	Policy	Description	Effectiveness of Implementation
			Science, Technology and Innovation ("STI") by leveraging and improving the coordination of existing STI programmes such as those with the Mining Equipment Manufacturers of South Africa to create innovation and product opportunities for locally developed mining equipment. These indicators will assist in the development of the 4IR within the mining sector by providing key policies and strategies to guide the changes that will arise as a result of the 4IR.
3	**Industrial Policy Action Plan ("IPAP")**	• IPAP aims to promote industrial development and competitiveness in South Africa, with a specific focus on 4IR technologies such as advanced manufacturing and digital industries (Department of Trade Industry and Competition, 2019). • The plan also focuses on increasing investment in research and development and improving the country's innovation ecosystem (Department of Trade Industry and Competition, 2019). • IPAP addresses the 4IR by focusing on building the necessary enablers for Industry 4.0 such as (Department of Trade Industry and Competition, 2019):	The IPAP has implemented a number of Key Action Programmes specific to the minerals beneficiation sector aimed at promoting the long-term growth and sustainability of the sector. These Programmes have been detailed as part of the IPAP and include the nature and purpose of the intervention, targeted outcomes, key milestones and specific projects to be implemented as part of the Programmes. These Programmes include (The Department of Trade, Industry and Competition, 2019): • Interventions for a sustainable steel industry including targeting investment growth within the steel value chain and technological upgrades in the short-to-medium term.

#	Policy	Description	Effectiveness of Implementation
		○ Developing a skilled workforce and support for worker retraining ○ Improving access to finance for small and medium-sized enterprises (“SMEs”) ○ Improving the country’s infrastructure to support the growth of the manufacturing sector ○ Encouraging investment in research and development, including in advanced technologies such as artificial intelligence, the IoT, and big data analytics.	• Expansion of the PGM beneficiation industries through the development of the Fuel Cell industry. Fuel cells offer health and safety benefits to conventional diesel as well as electric mining equipment in underground applications as an integrated technology solution, making this a key Programme to take note of within the MMS. • The development of energy storage technology in South Africa to meet the projected global up-take of vanadium energy storage solutions. This Programme will require South Africa to demonstrate its ability to implement innovative technologies in line with global standards. • Growing the market share of domestic manufacturers of mining equipment and components by identifying opportunities for localisation, supplier development and export growth. This Programme, spearheaded by the Mandela Mining Precinct will include projects such as: ○ Modernisation of current operational mines. ○ Mechanised mining for gold and platinum. ○ Non-explosive rock breaking.

#	Policy	Description	Effectiveness of Implementation
			○ Advanced ore-body knowledge. ○ Real-time information management systems and Mining 4.0. ○ Optimisation of the mining supply chain. The abovementioned Programmes, along with growing the sector as a whole, aim to enhance innovation and the technological capacity of the sector to ensure global competitiveness and build the necessary capacity to enable the adoption of the 4IR.

6 Geographic Distribution

This section provides an overview of the geographic distribution of employers and training providers within the MMS who completed the Skills Demand and Supply Survey.

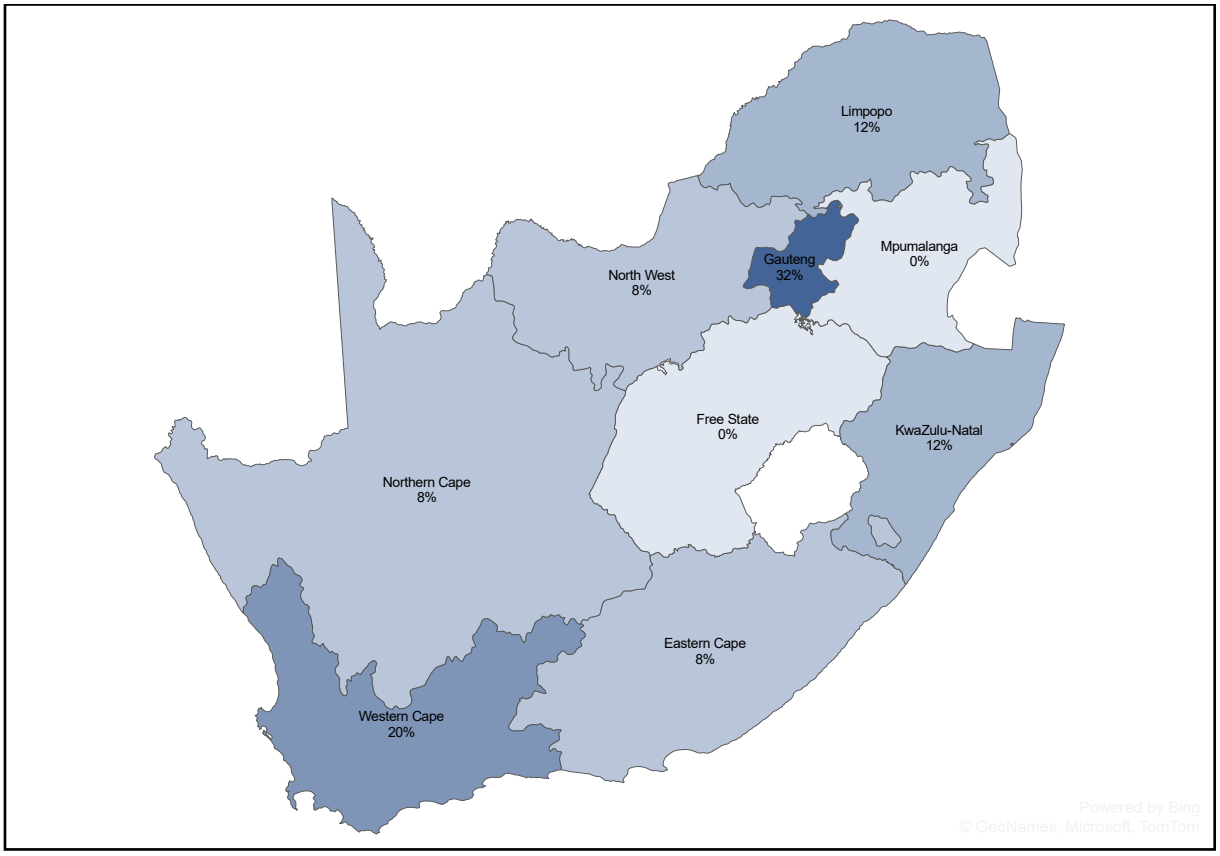
6.1 Employers

This section provides an overview of the geographic distribution of employers, per MMS sub-sector. The geographical data contained in this section provides a practical view of where key employers[19] are located; and thus, assists with the conceptualisation of sub-sector footprints.

6.1.1 CLAS Mining

The following figure shows the geographical footprint of surveyed employers operating in the CLAS mining sub-sector.

Figure 6-1: Geographic Footprint of CLAS Mining



Source: MQA Skills Demand and Supply Survey, 2023

As can be seen above, almost one third (32%) of the surveyed CLAS mining sub-sector employers are located in Gauteng. The Western Cape (20%), Kwa-Zulu Natal (12%),

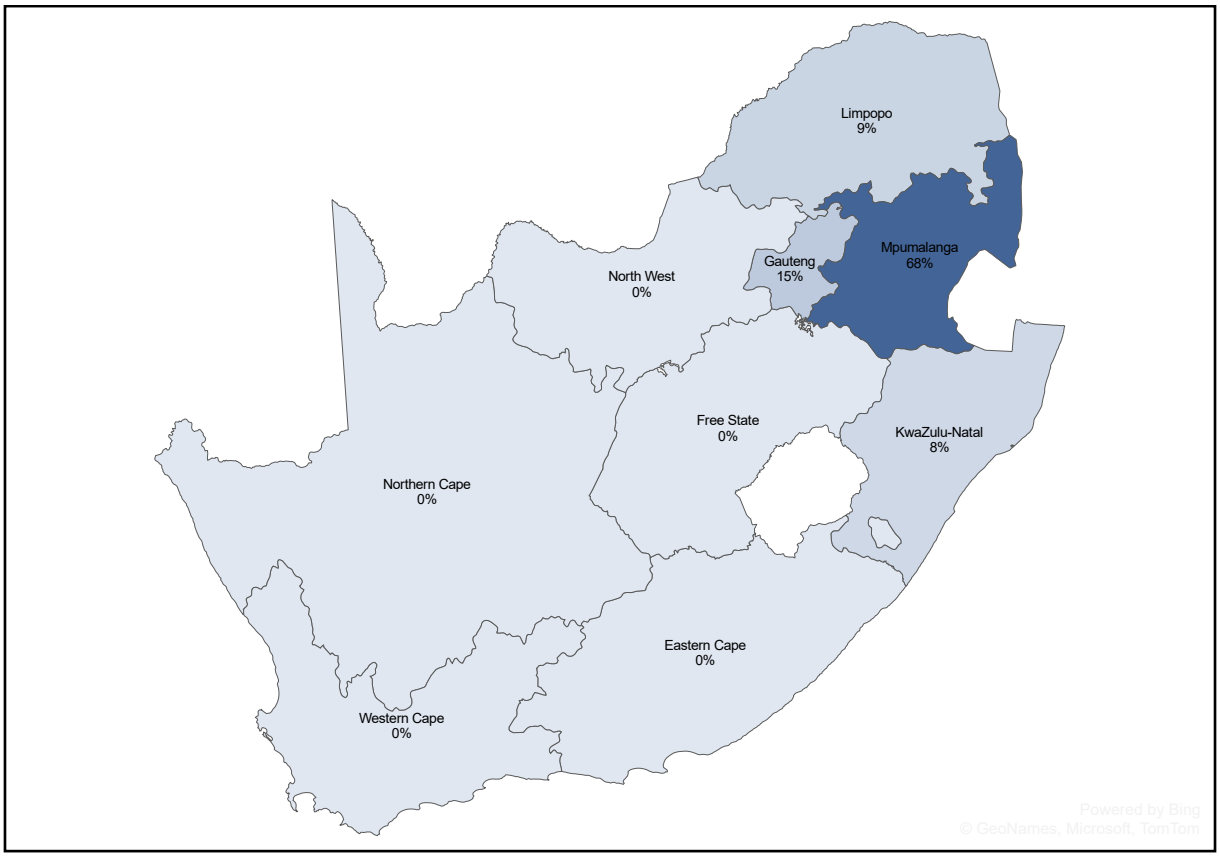
[19] Reference to 'employers' within the context of this report refers to representatives within MMS organisations. These representatives occupied a range of different roles within their organisations such as Human Resource Development Managers, Learning and Development Managers, Business Owners, Training Superintendents, Talent Management Specialists, Business Directors, Compliance Managers, Human Resource Consultants, Operations Directors, and Skills Development Facilitators.

and Limpopo (12%) represent a joint 44% of CLAS mining sub-sector employers. The remaining CLAS mining sub-sector employers surveyed, are located within the Northern Cape (8%), Eastern Cape (8%), and North West (8%).

6.1.2 Coal Mining

The following figure shows the geographical footprint of surveyed employers operating in the coal mining sub-sector.

Figure 6-2: Geographic Footprint of Coal Mining



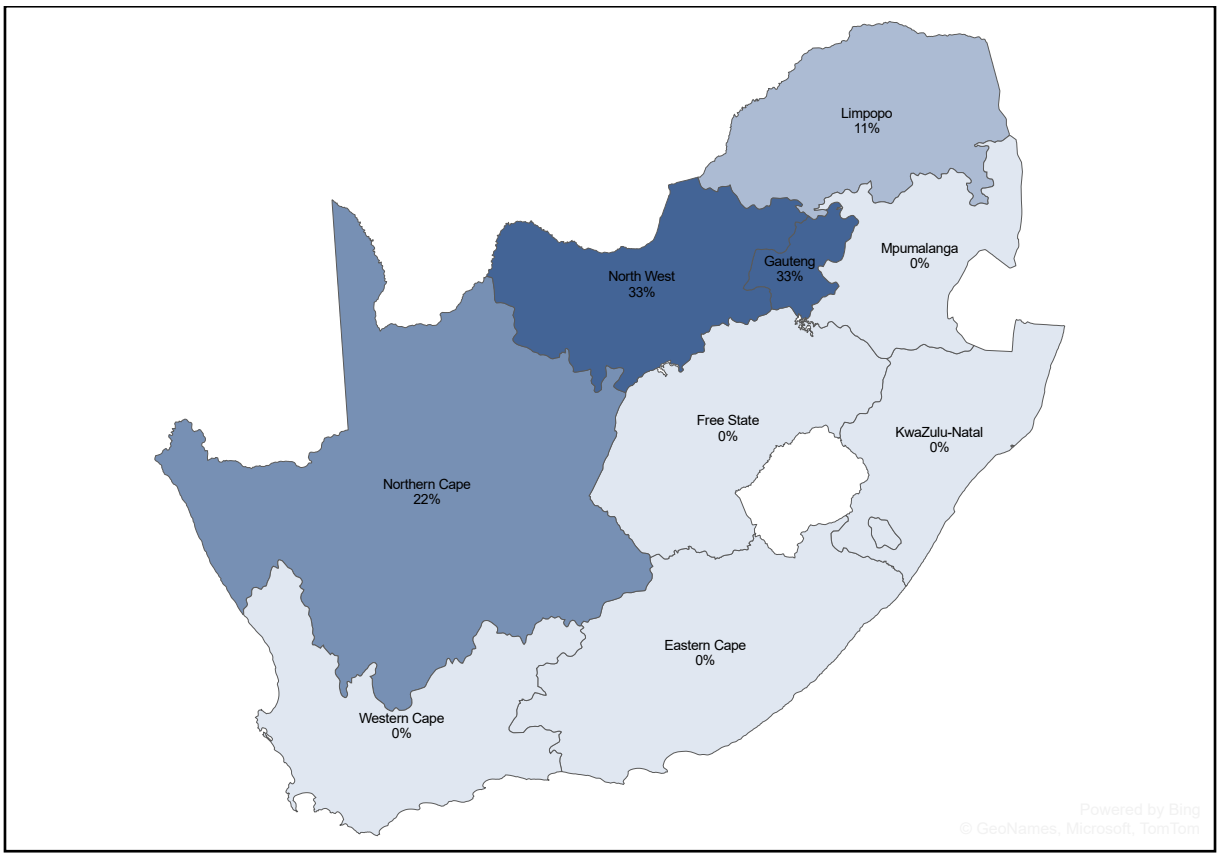
Source: MQA Skills Demand and Supply Survey, 2023

As can be seen, the highest number surveyed employers operating in the coal mining sub-sector are located within Mpumalanga (68%) followed by Gauteng (15%), Limpopo (9%), and Kwa-Zulu Natal (8%).

6.1.3 Diamond Mining

The following figure illustrates the geographical footprint of surveyed employers operating in the diamond mining sub-sector.

Figure 6-3: Geographic Footprint of Diamond Mining



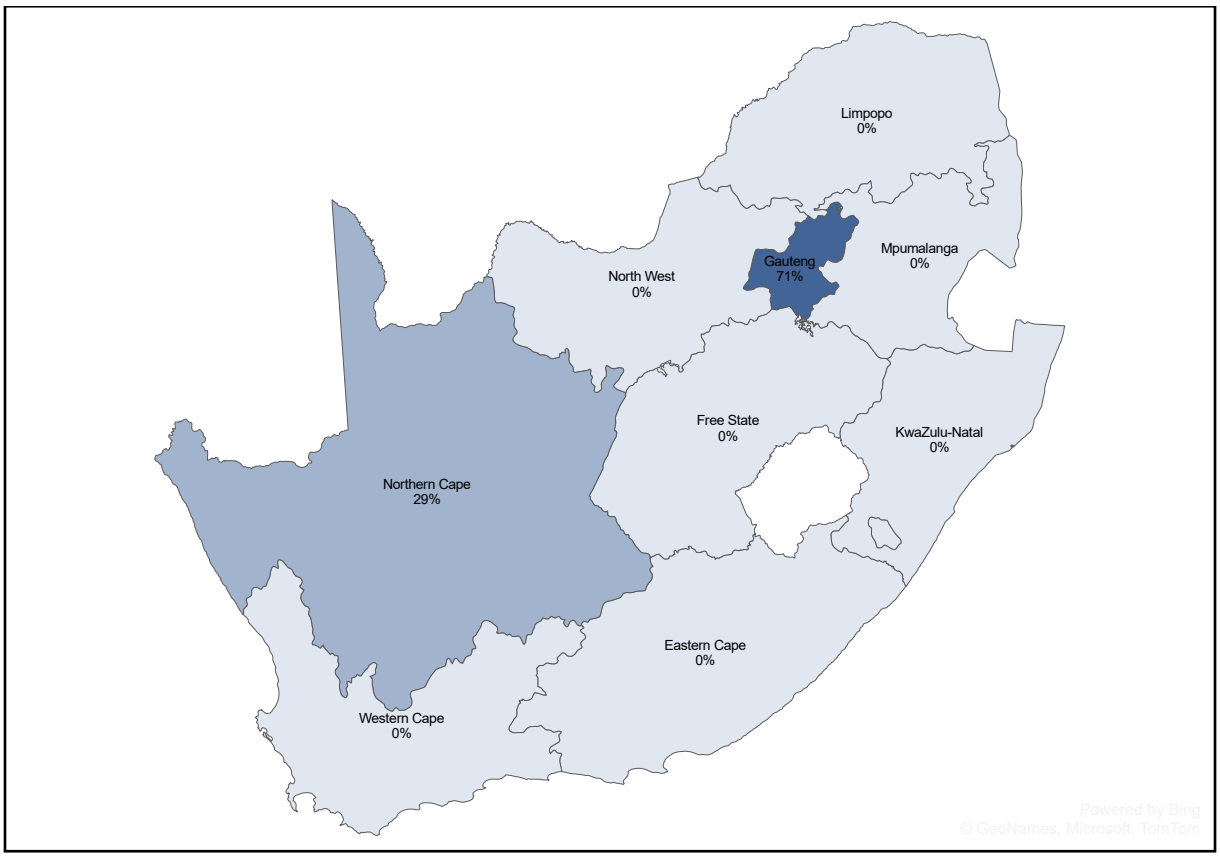
Source: MQA Skills Demand and Supply Survey, 2023

As seen in the map above, the highest number of surveyed employers operating in the diamond mining sub-sector are located in Gauteng (33%) and the North West (33%). The remaining employers operating in the diamond mining sub-sector are located in Northern Cape (22%) and Limpopo (11%).

6.1.4 Diamond Processing

The following figure illustrates the geographical footprint of surveyed employers operating in the diamond processing sub-sector.

Figure 6-4: Geographic Footprint of Diamond Processing



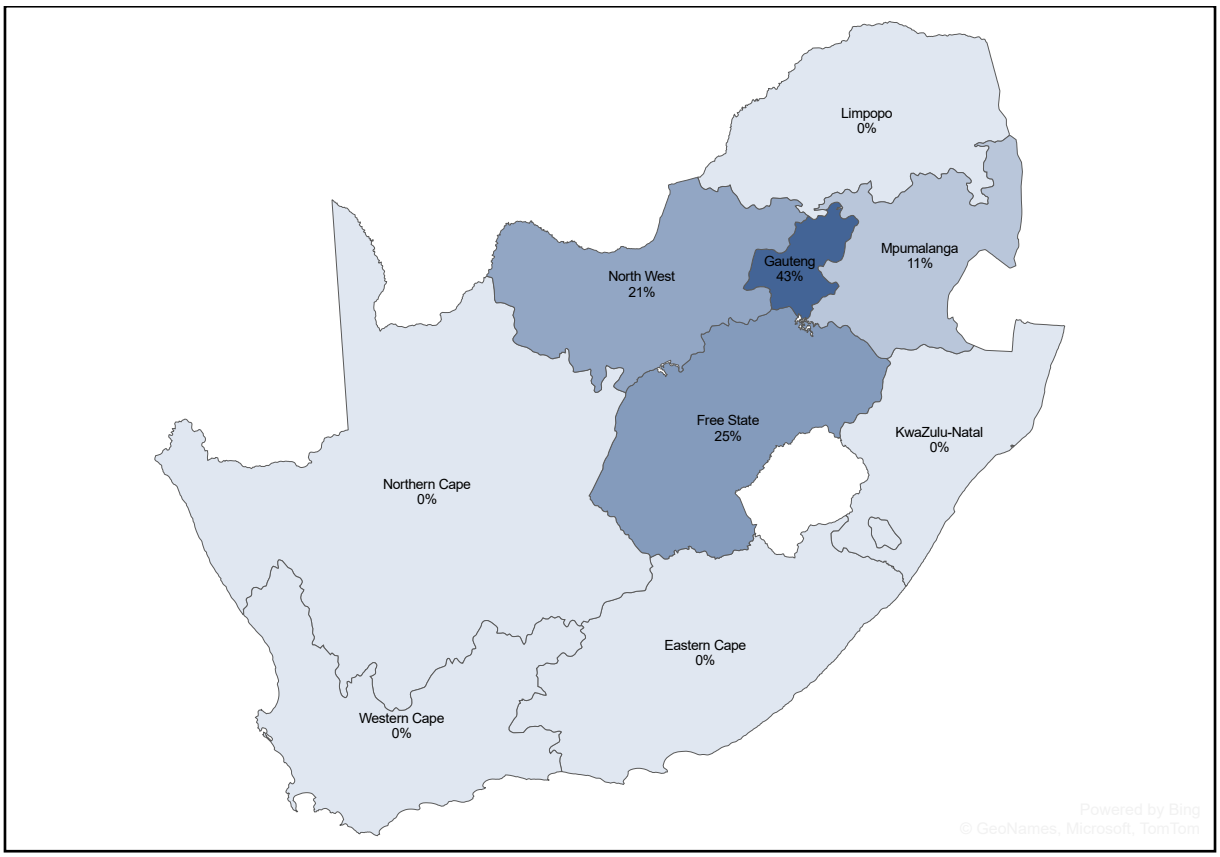
Source: MQA Skills Demand and Supply Survey, 2023

As seen above, all surveyed employers operating in the diamond processing sub-sector are located in Gauteng (71%) and the Northern Cape (29%).

6.1.5 Gold Mining

The following figure illustrates the geographical footprint of surveyed employers operating in the gold mining sub-sector.

Figure 6-5: Geographic Footprint of Gold Mining



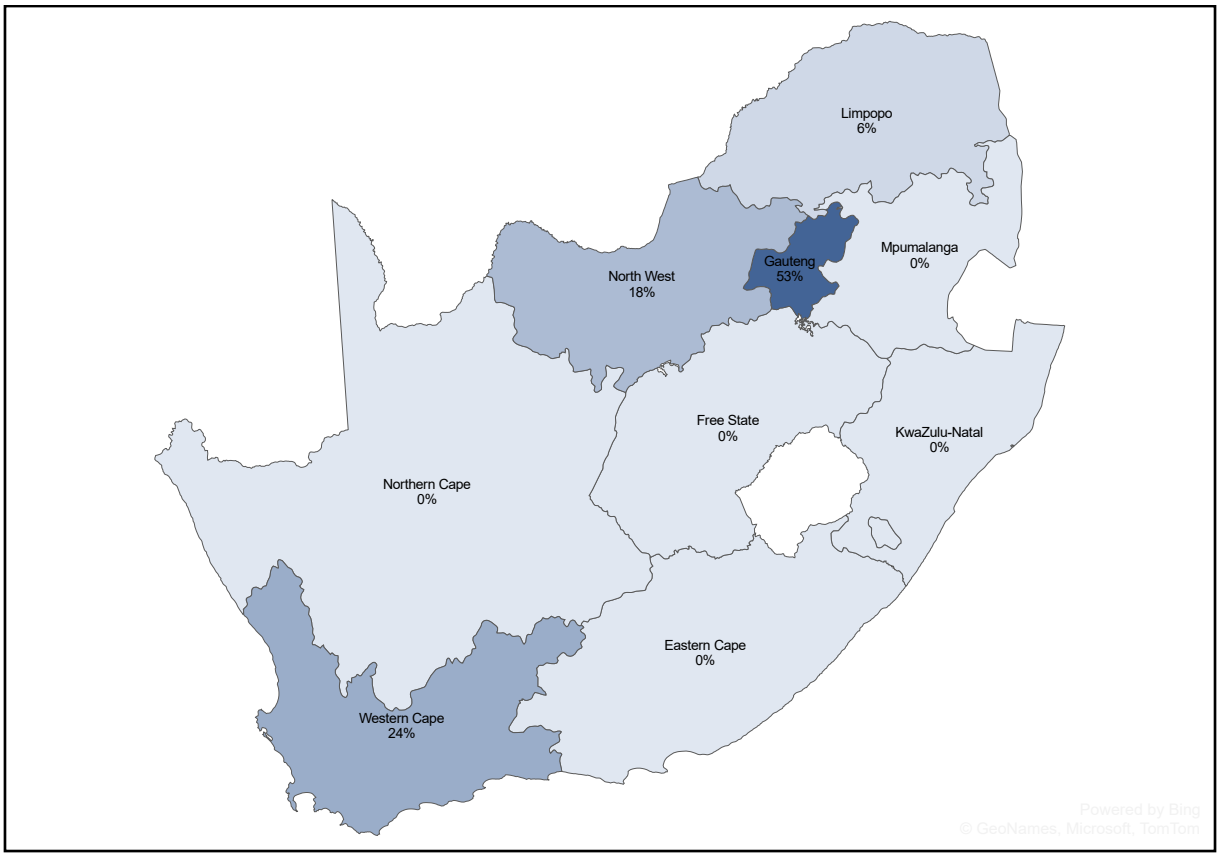
Source: MQA Skills Demand and Supply Survey, 2023

As can be seen on the map above, the highest number of surveyed employers operating in the gold mining sub-sector are located within Gauteng (43%). The remaining respondents indicated that their operations are based in the Free State (25%), North West (21%) and Mpumalanga (11%).

6.1.6 Jewellery Manufacturing

The following figure shows the geographical footprint of surveyed employers operating in the jewellery manufacturing sub-sector.

Figure 6-6: Geographic Footprint of Jewellery Manufacturing



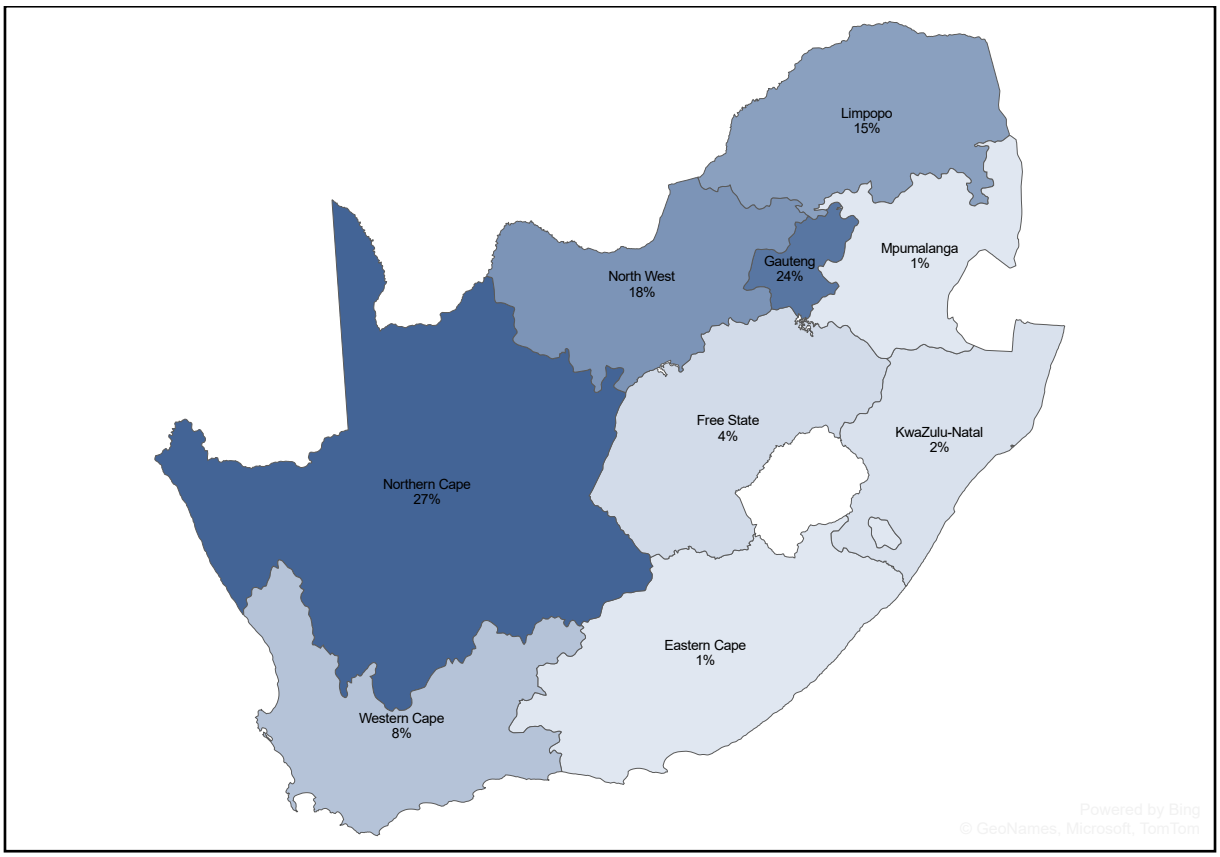
Source: MQA Skills Demand and Supply Survey, 2023

Employers operating in the jewellery manufacturing sub-sector are represented in 4 of 9 provinces across the country. Gauteng holds majority of representation at 53%, followed by the Western Cape (24%), the North West (18%) and Limpopo (6%).

6.1.7 Other Mining

The following figure illustrates the geographical footprint of surveyed employers operating in the other mining subsector.

Figure 6-7: Geographic Footprint of 'Other' Mining



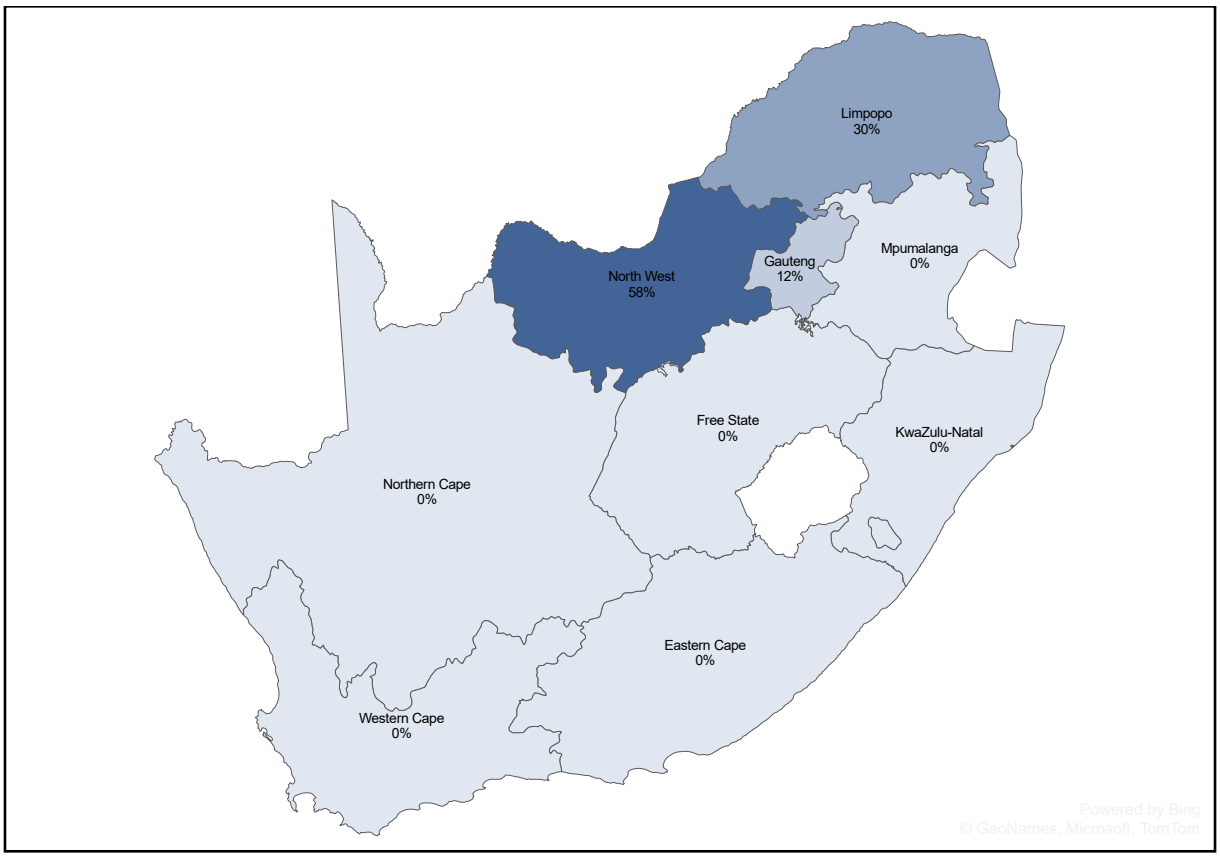
Source: MQA Skills Demand and Supply Survey, 2023

This sector encompasses the extraction and processing of minerals including uranium, iron ore, chrome, manganese, copper, phosphates, and salt. The above map indicates that the just over a quarter of surveyed employers operating in the other mining sub-sector are located in the Northern Cape (27%) followed by Gauteng (24%) and the North West (18%). Surveyed employers located in Limpopo and the Western Cape make up 15% and 8% of the surveyed employers operating in the other mining sub-sector respectively. 4% of the surveyed employers are located the Free State whilst 2% are located in KwaZulu-Natal. The Eastern Cape and Mpumalanga had the least number of respondents with 1% each.

6.1.8 PGM Mining

The following figure illustrates the geographical footprint of surveyed employers operating in the PGM mining sub-sector.

Figure 6-8: Geographic Footprint of PGM Mining



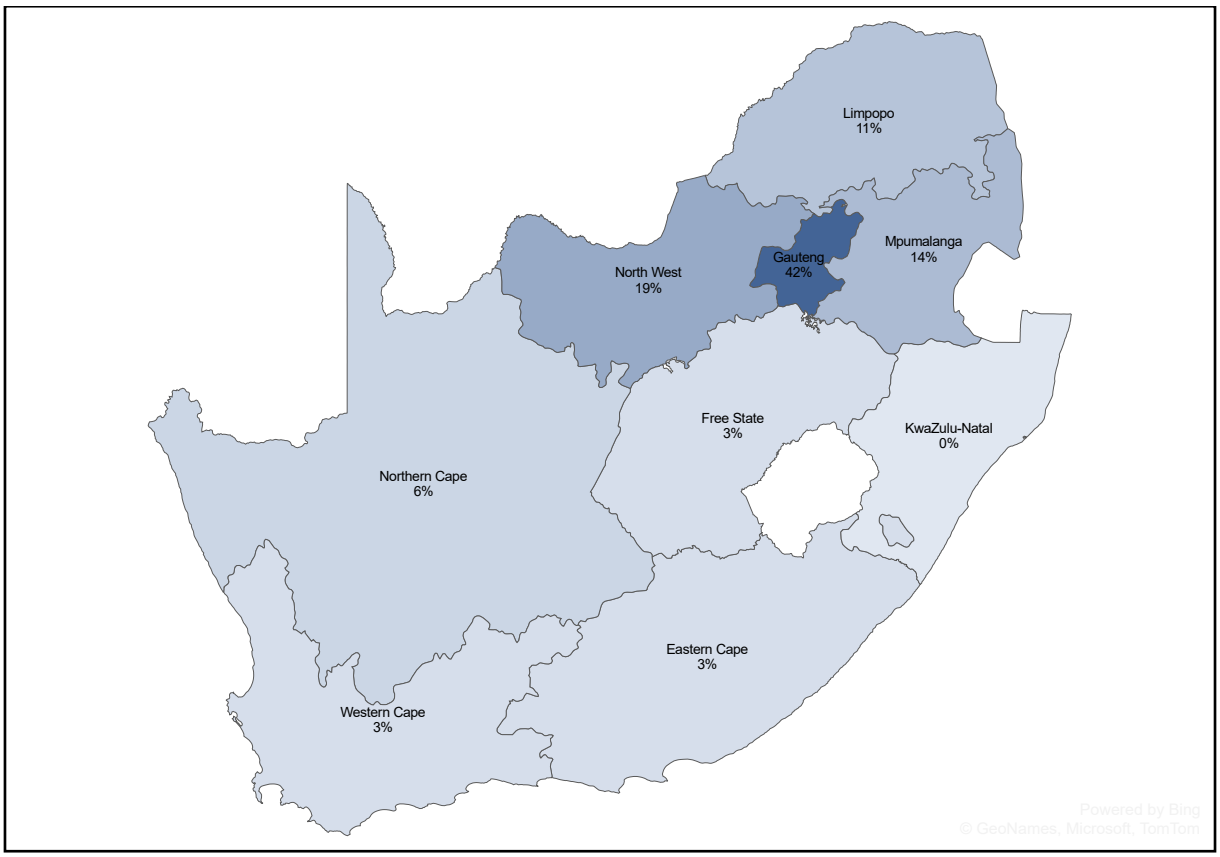
Source: MQA Skills Demand and Supply Survey, 2023

All of the surveyed employers within the PGM sub-sector are located within three provinces namely, the North West (58%), Limpopo (30%) and Gauteng (12%).

6.1.9 Services Incidental to Mining

The following figure shows the geographical footprint of surveyed employers operating in the services incidental to mining sub-sector.

Figure 6-9: Geographic Footprint of Services Incidental to Mining



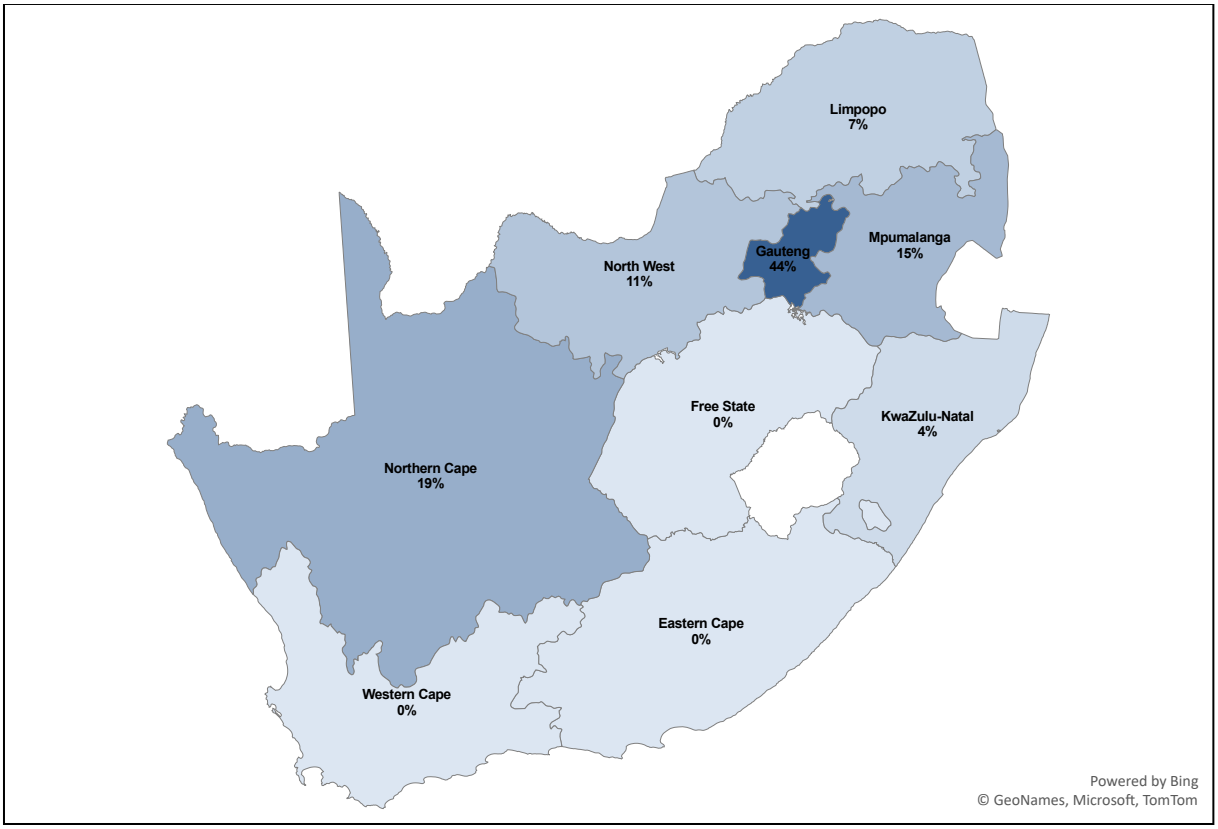
Source: MQA Skills Demand and Supply Survey, 2023

The services incidental to mining sub-sector comprises of companies that offer services closely associated with the MMS, including research and development in mining and mineral extraction, training, catering, payroll management, machinery and equipment manufacturing, distribution, hiring and maintenance, consulting, shaft sinking, as well as transportation and logistics. The map above indicates that almost half (42%) of surveyed employers in this sector are located in Gauteng. Employers in the North West (19%), Mpumalanga (14%), and Limpopo (11%) subsequently represent a joint 44% of surveyed employers in the sub-sector. Employers in the Northern Cape (6%), Western Cape (3%), Eastern Cape (3%), and Free State (3%) represent a smaller proportion of surveyed employers in the sub-sector.

6.2 Training Providers

The figure below shows the provincial distribution of surveyed training providers.

Figure 6-10: Geographic Footprint of Training Providers



Source: MQA Skills Demand and Supply Survey, 2023

As can be seen above, almost half (44%) of the training providers that currently offer learning programmes within the MMS are based in Gauteng. This is followed by the Northern Cape (19%), Mpumalanga (15%), North West (11%) and Limpopo (7%). The high number of training providers within the abovementioned provinces may be due to the higher concentration of mines and mining workforces located within said provinces (StatisticsSA, 2019). Kwa-Zulu Natal has the least number of respondents at 4%.

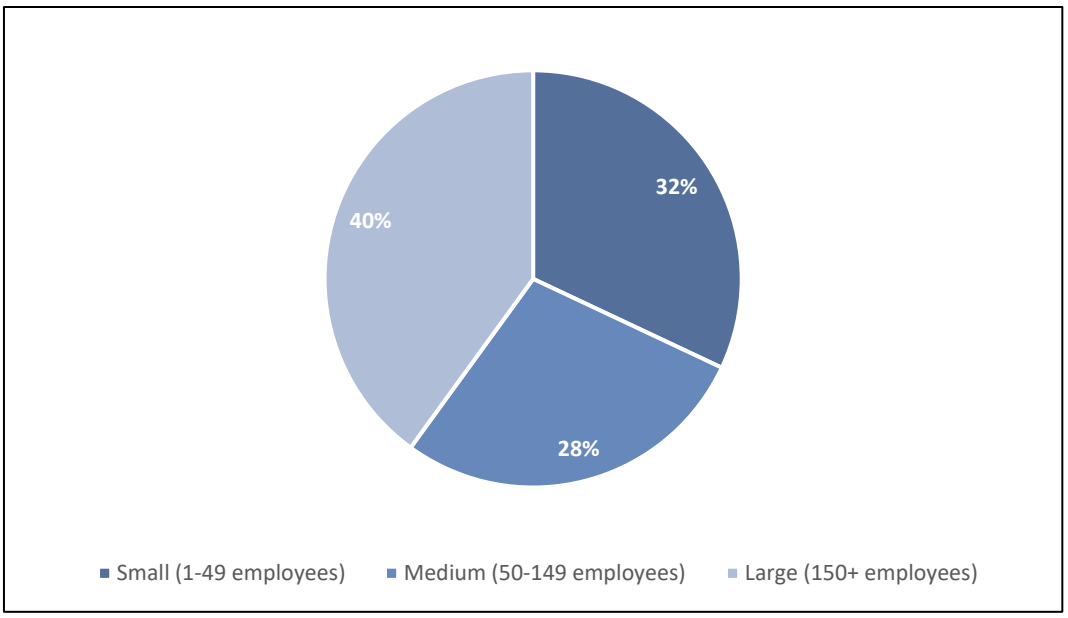
7 Organisation Size

This section provides an overview of the different MMS organisation size types, per sub-sector. Employers from the various MMS sectors were requested to disclose whether they were representative of small (1-49 employees), medium (50-150 employees), or large (150+ employees) mining operations.

7.1 CLAS

The figure below illustrates the organisational size of surveyed employers operating in the CLAS mining sub-sector.

Figure 7-1: Organisation Size – CLAS Mining



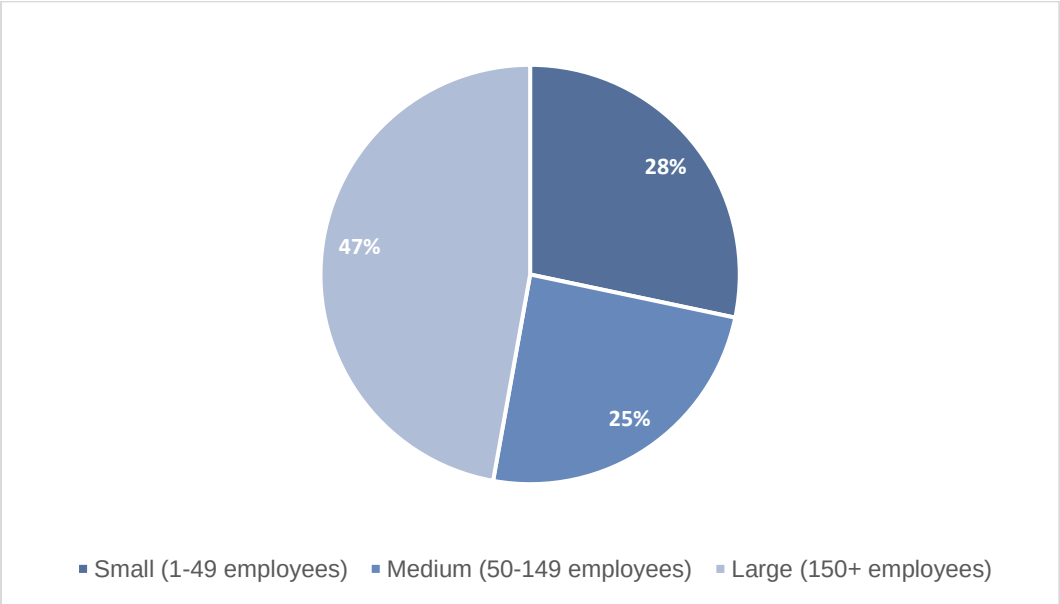
Source: MQA Skills Demand and Supply Survey, 2023

As seen in the graph above, 40% of surveyed employers within the CLAS mining sub-sector represent large CLAS organisations, whilst 32% represent small organisations. The remaining 28% represent medium-sized organisations.

7.2 Coal Mining

The figure below illustrates the organisational size of surveyed employers operating in the coal mining sub-sector.

Figure 7-2: Organisation Size - Coal Mining



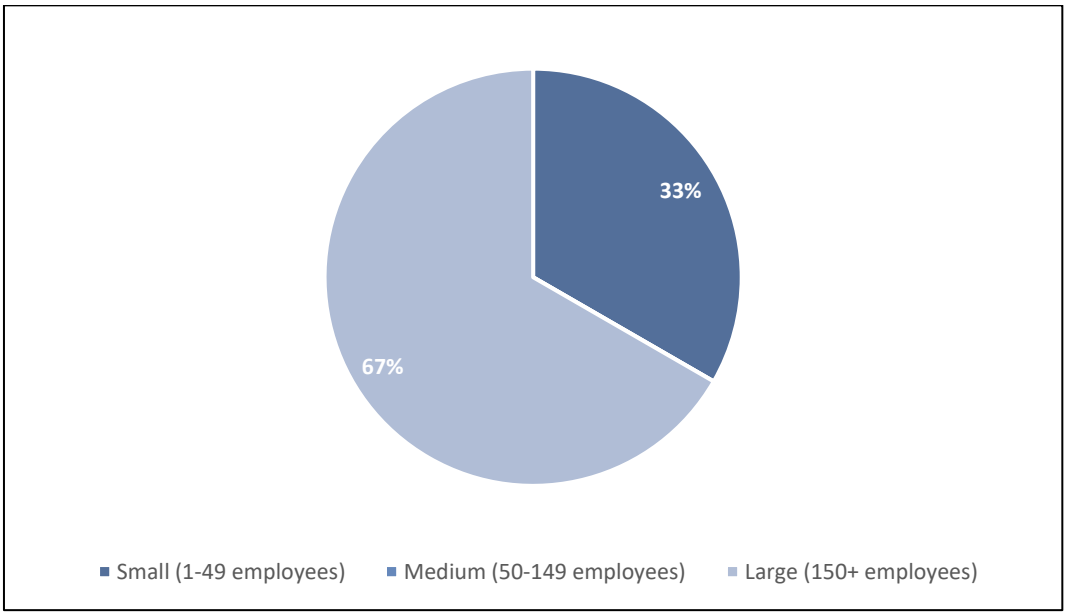
Source: MQA Skills Demand and Supply Survey, 2023

As seen in the graph above, 47% of surveyed employers within the coal mining sub-sector represent large organisations, whilst 28% represent small organisations. The remaining 25% represent medium-sized organisations.

7.3 Diamond Mining

The figure below illustrates the organisational size of surveyed employers operating in the diamond mining sub-sector.

Figure 7-3: Organisation Size - Diamond Mining



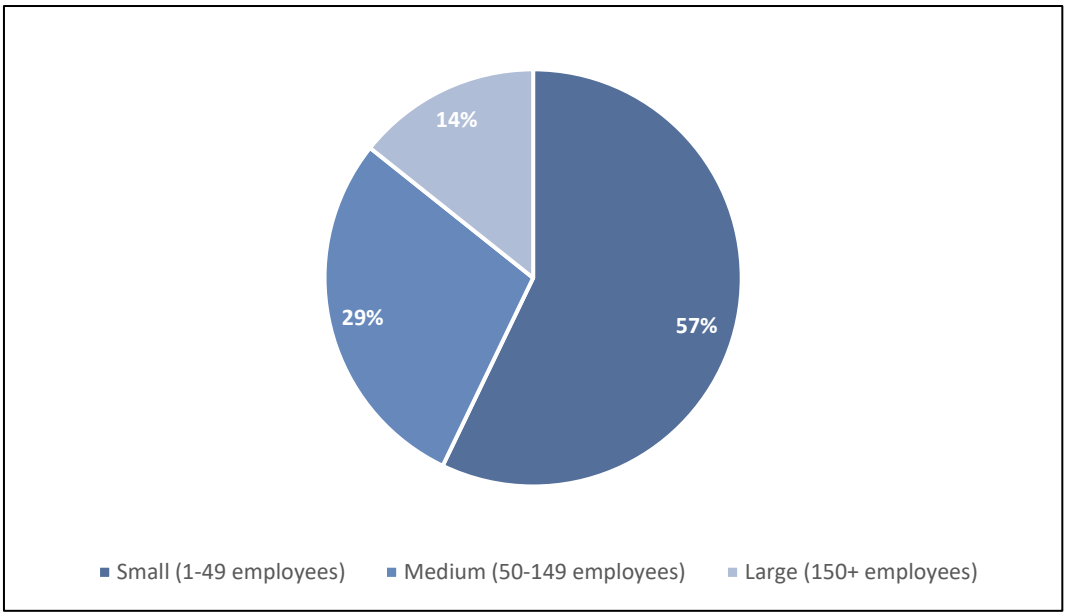
Source: MQA Skills Demand and Supply Survey, 2023

The figure above shows that only two types of organisation sizes are represented for the diamond mining sub-sector. The majority (67%) of surveyed employers represent large organisations within the diamond mining sub-sector whilst the remaining 33% represent small organisations.

7.4 Diamond Processing

The figure below illustrates the organisational size of surveyed employers operating in the diamond processing sub-sector.

Figure 7-4: Organisation Size - Diamond Processing



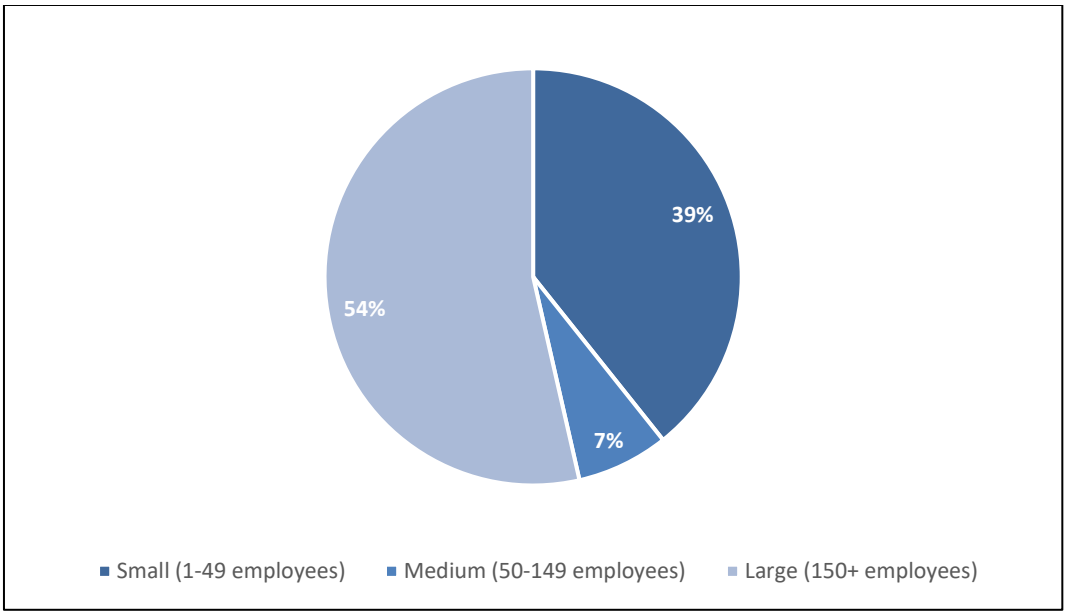
Source: MQA Skills Demand and Supply Survey, 2023

The figure above indicates that just over half (57%) of surveyed employers in the diamond processing sub-sector represent small organisations. 29% of surveyed employers represent medium-sized diamond processing organisations whilst the remaining 14% of surveyed employers represent large organisations.

7.5 Gold Mining

The figure below illustrates the organisational size of surveyed employers operating in the gold mining sub-sector.

Figure 7-5: Organisation Size - Gold Mining



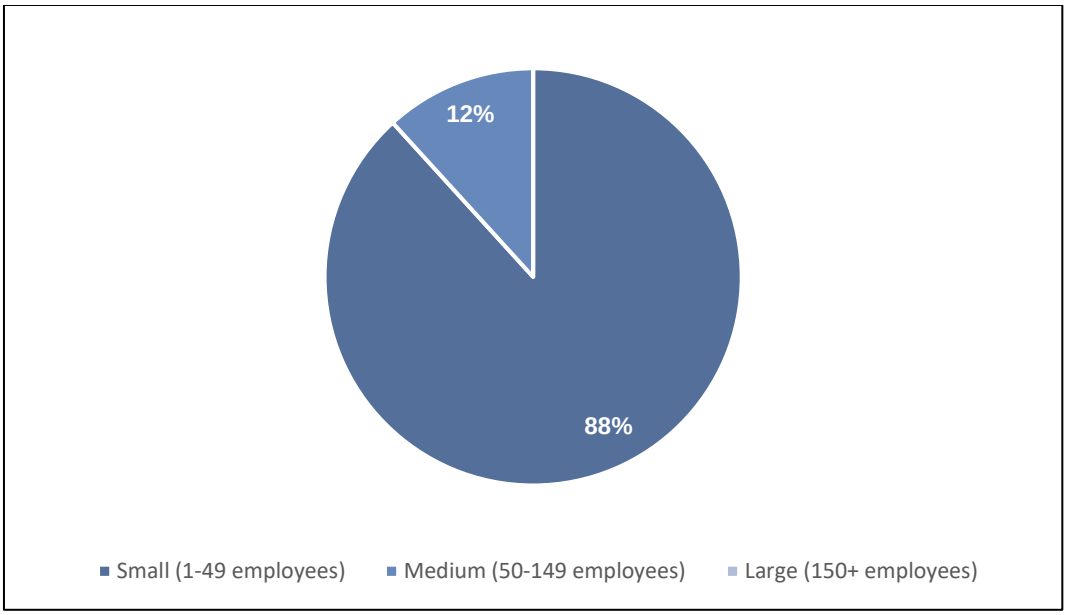
Source: MQA Skills Demand and Supply Survey, 2023

The figure above indicates that just over half (54%) of surveyed employers in the gold mining sub-sector represent large organisations. 39% of surveyed employers represent small gold mining organisations whilst the remaining 7% of surveyed employers represent medium-sized organisations in the gold mining sub-sector.

7.6 Jewellery Manufacturing

The figure below illustrates the organisational size of surveyed employers operating in the jewellery manufacturing sub-sector.

Figure 7-6: Organisation Size - Jewellery Manufacturing



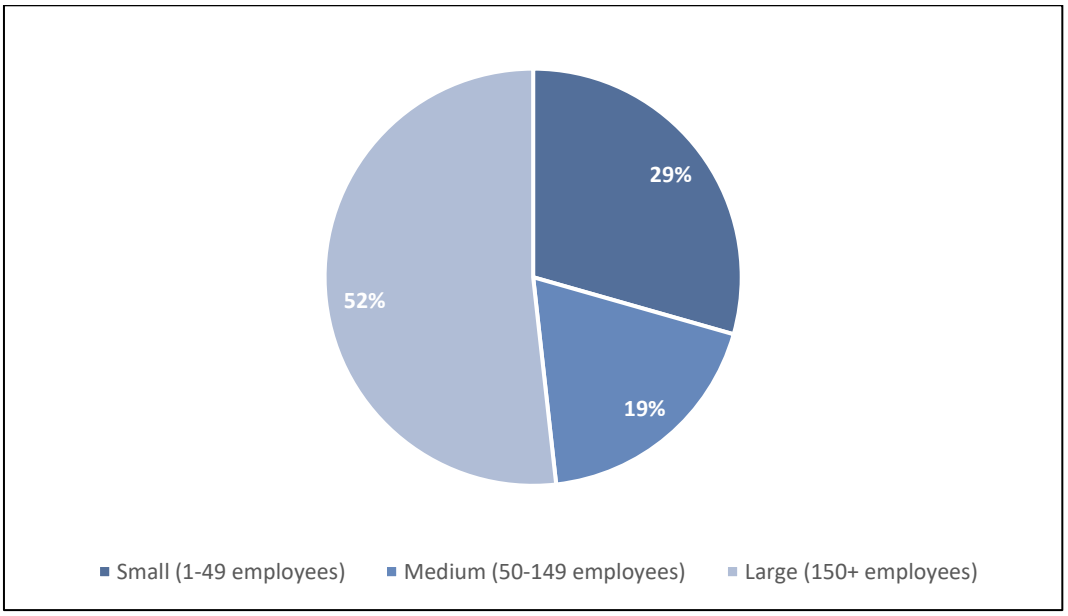
Source: MQA Skills Demand and Supply Survey, 2023

The figure above shows that only two types of organisation sizes are represented in the jewellery manufacturing sub-sector, namely small and medium sized organisations. The majority (88%) of surveyed employers represent small organisations within the jewellery manufacturing sub-sector whilst the remaining 12% represent medium-sized organisations.

7.7 Other Mining

The figure below illustrates the organisational size of surveyed employers operating in the other mining sub-sector.

Figure 7-7: Organisation Size - Other Mining



Source: MQA Skills Demand and Supply Survey, 2023

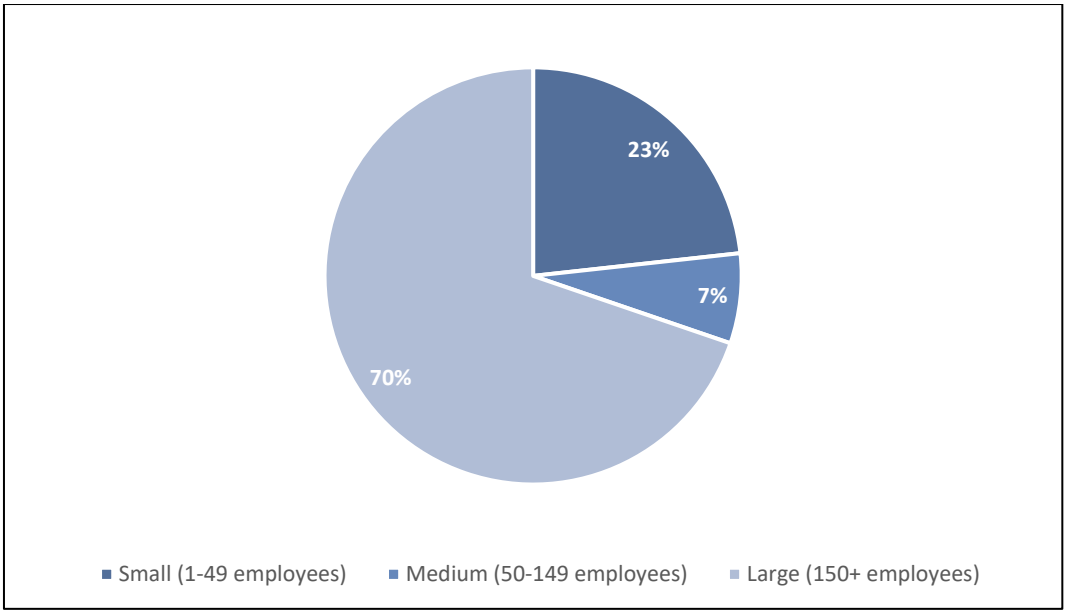
The figure above indicates that just over half (52%) of surveyed employers in the other mining sub-sector represent large organisations. 29% of surveyed employers

represent small other mining organisations whilst the remaining 19% of surveyed employers represent medium-sized organisations in the other mining sub-sector.

7.8 PGM Mining

The figure below illustrates the organisational size of surveyed employers operating in the PGM mining sub-sector.

Figure 7-8: Organisation Size - PGM Mining



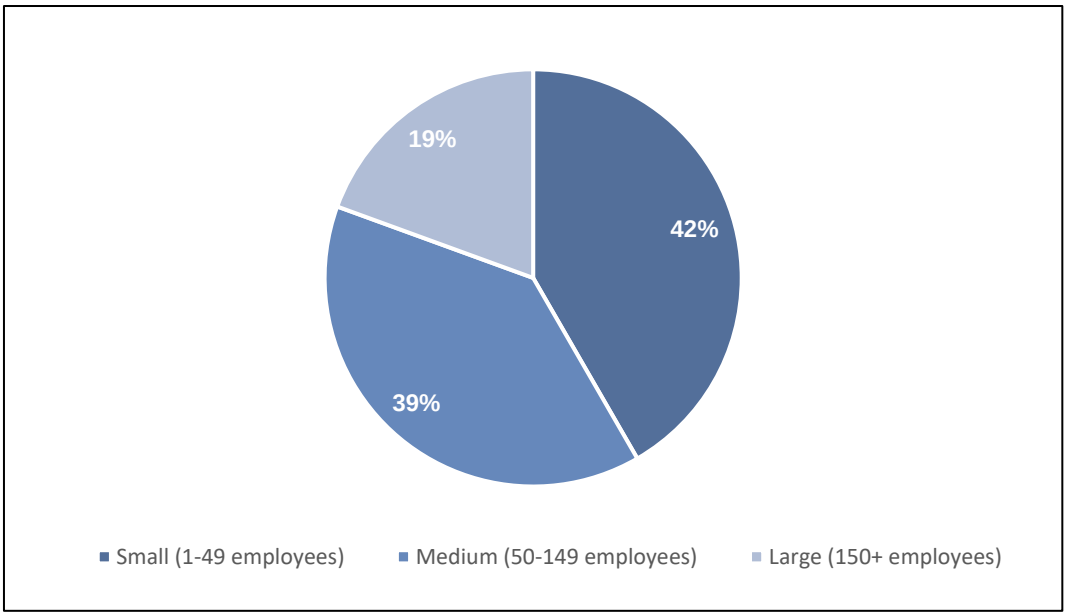
Source: MQA Skills Demand and Supply Survey, 2023

The figure above indicates that the majority (70%) of surveyed employers in the PGM mining sub-sector represent large organisations. 23% of surveyed employers represent small PGM organisations whilst the remining 7% of surveyed employers represent medium-sized organisations in the PGM sub-sector.

7.9 Services Incidental to Mining

The figure below illustrates the organisational size of surveyed employers operating in the services incidental to mining sub-sector.

Figure 7-9: Organisation Size – Services Incidental to Mining



Source: MQA Skills Demand and Supply Survey, 2023

As illustrated above, the services incidental to mining sub-sector is largely represented by small organisations (42%) that participated in the study. 39% of surveyed employers represent medium-sized organisations whilst the remaining 19% represent large organisations.

8 Findings: Skills Demand

This section presents findings on the nature of skills demand in the MMS. The findings provide insight on the impact of changing technology on the sector and the impact of changing technology on occupations and skills in the sector. This section also provides an overview of HTFVs and occupational shortages within the MMS. This analysis is instructive in informing one where employment opportunities may be within the sector, but also indicates the required skills needed to help support sector growth and/or sustainability in the context of everchanging technological developments and changes. The following sub-sectors are discussed below:

- CLAS;
- Coal Mining;
- Diamond Mining;
- Diamond Processing;
- Gold Mining;
- Jewellery Manufacturing;
- Other Mining;
- PGM Mining; and
- Services Incidental to Mining.

8.1 Impact of Changing Technology on the MMS

This section details the impact of changing technology on the MMS. It is important to first consider what the impact of changing technology has been on the MMS, as it contextualises the current MMS landscape, which provides a foundation from which the impact of changing technology on occupations and skills can be explored.

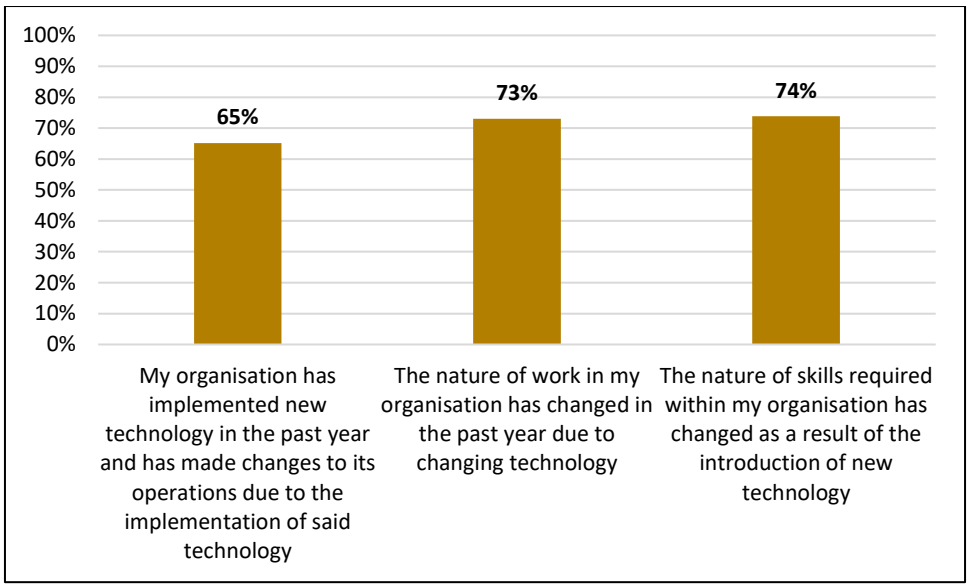
As seen below, 65% of employers indicated that their organisation has implemented new technology in the past year and have made changes to operations due to the implementation of said technology. Similarly, 73% of employers indicated that the nature of work has changed within their organisation due to the implementation of changing technology in the past year. Qualitative consultations with employers in the MMS revealed that that the most drastic change regarding the nature of work pertains to transitioning from performing certain tasks manually, such as the driving of haulage tricks, to operating software and related machinery that control the new technologies implemented to perform the same tasks.

> "Yes, an autonomous vehicle needs a person at the other end to [operate] it still. So, it is not like it can do its own thing yet. There is still a person sitting behind a laptop or whatever screen driving the machine. I think at the end of the day, the man that drives that vehicle physically, you are going to have to teach him to be electronically minded sitting behind the screen. You might not have to cut down too many jobs."
>
> *Employer Interview 2, 2023 (Gold Mining)*

These operational related changes, as well as those associated with the changing nature of work, appear to have impacted on the skills required within organisations,

with 74% of employers indicating that the nature of skills required within their organisation has changed due to the introduction of new technologies.

Figure 8-1: The Impact of Changing Technology on Operations and Skills



Source: MQA Skills Demand and Supply Survey, 2023

Consulted stakeholders have indicated that the introduction of more sophisticated technologies poses several potential benefits to the MMS. This includes increased efficiency, with employers indicating that the integration of new technologies may result in more efficient operations, reduced time expenditures, and increased overall productivity. In addition to increased efficiency, qualitative insights from employers indicate that the incorporation of technologies such as automation will play a pivotal role in elevating safety standards by minimising human exposure to hazardous environments.

> "The [biggest impact] that comes to mind [is that] 4IR technologies could improve [the] safety and well-being of employees. In terms of safety, it is going to pull out the employee from exposure to dangers like dust, noise, and smoke, because they will now be working from a remote location. [4IR technologies] will [also] improve efficiency and productivity, the programs put in place are efficiency based. This will obviously improve the achievement of our goals, and that is to produce the mineral."
>
> *Employer Interview 10, 2023 (Coal Mining)*

However, while there is an appreciation for the changing technologies associated with 4IR and the potential benefits thereof in the sector, stakeholders have indicated that they do not foresee 4IR having a sizable impact on the sector (at least in the short term) due to various reasons. Insights from the qualitative data indicate that limited capital is a barrier to 4IR technology implementation, with several employers indicating that financial constraints limit their ability to invest in 4IR technologies, particularly

when considering the significant capital outlay associated with the acquisition of 4IR related machinery, software, and programmes.

> "The biggest thing [for our organisation] is the cost of everything. It is easy to say let's automate, but everything comes with a price, and we cannot afford it. If we had the resources to bring in all this new technology, software, and machinery, we would not have an issue [implementing new technology]."
>
> *Employer Interview 17, 2023 (Diamond Mining)*

Other employers echoed these sentiments, noting that a lack of funding, as well as a lack of skilled personnel are factors impacting on their ability to introduce new technology within their operations.

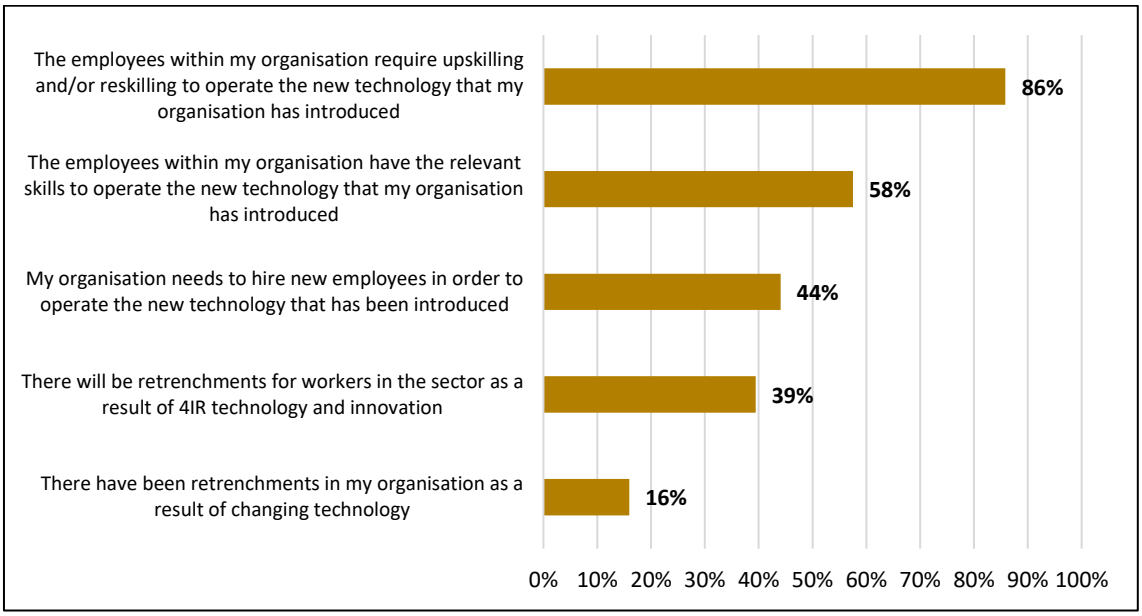
> "Funding is the main thing. Mining is very complex with a lot of things going on. Machines are not cheap. There are no people who have skills to use the machines. The right skills need to come first. Determine what the future will look like and what skills will be needed. We need to create the skills and make technology available to use."
>
> *Employer Interview 6, 2023 (PGM)*

Organisation size also appears to be a factor which exacerbates the financial challenge, with several employer representatives from small organisations indicating that they do not have the financial capital to invest in changing and 4IR-related technologies, further noting that the cost associated with the implementation of new technologies would not result in meaningful benefits for their organisation.

> "For us it is expensive to adopt new technologies – the expense, lack of skills, and lack of knowledge do not weigh up to the benefit gained, especially for us because we are so small. We will not really gain much, but it would cost us a lot."
>
> *Employer Interview 18, 2023 (Diamond Mining)*

In addition to financial constraints, another challenge noted by employers regarding the mechanisation of their operations is the extent of upskilling that is required to ensure that their employees are equipped with the skills to operate and manage more sophisticated machinery. This view was corroborated by the quantitative data, as can be seen below.

Figure 8-2: Impact of Changing Technology on Occupational & Skills Requirements



Source: MQA Skills Demand and Supply Survey, 2023

As can be seen above only 58% of employers indicated that their employees have the relevant skills to operate the new technology that their organisation has introduced. Furthermore, 86% of employers were of the view that the employees within their organisation require upskilling and/or reskilling to operate the new technology that their organisation has introduced. These results highlight the extent of upskilling and/or reskilling that is required for employers to ensure that their employees have the relevant skills to work with more sophisticated machinery. When considering that many employees within the sector have low levels of education; the challenge for employers in terms of upskilling is exacerbated. Furthermore, upskilling also has a significant cost attached, which is an additional consideration for organisations within the sector.

> "In terms of technology, our main challenge is upskilling our people like boilermakers, fitters and artisans. It is very costly - we have even started a funding scheme so that we can upskill them. The other thing is that we cannot wait for our employees to be qualified, so we end up recruiting from outside. We also have a challenge because while we are considered to be a mine technically, we are not the same as industry giants like [name redacted] who have the resources to train employees continuously."
>
> *Employer Interview 16, 2023 (CLAS)*

Another barrier to 4IR technology implementation is a lack of understanding from employers in terms of the benefits of 4IR related technologies. Consulted employers have indicated that there is a lack of research on the benefits of the implementation of technology in the South African context, further indicating that research needs to be conducted to determine whether the benefits outweigh the costs of implementing new technologies. Several employers were of the view that it is cheaper to continue

conducting their operations as they have been doing, instead of transitioning to mechanised operations.

> "In my view there is a lack of research on the benefits of implementing technology in the South African context. Research needs to be conducted to see whether the benefits outweigh the costs of implementing new technologies. Sometimes the old way is the most feasible way because it is cheaper to continue conducting our operations as we have been doing, instead of transitioning to mechanised operations."
>
> *Employer Focus Group - Gauteng, 2023*

Similar sentiments were noted in other qualitative consultations, with certain employers noting that there appears to be resistance to change at both organisational and employee levels as it relates to the introduction of new technology. It was noted in several consultations that certain employers and employees still believe in conventional mining methods and that considerable effort must be placed to convince them of the benefits of the 4IR and associated technologies.

> "[The introduction of new technologies is not limited by] a lack of skills, that is for sure. When you bring in a new technology into the mine, it is because there is a need for that [technology]. Before you bring it, you have already identified how many people will be needed to support that technology. Before the machine is brought in, you have already done an analysis to find out if the people that will be brought in to operate the machine are ready or they need training. So, I would say [the introduction of new technologies is limited] by the fact that we still believe in the current way of doing things. I think it is because change needs to happen in our processes and how we inform our strategies. Lack of skills could not be an issue because organisations skill people as per the changes that are coming into the environment; maybe the cost factor might also be part of it, we know that mines are not doing as well as they used to. The commodities have gone down, you look at where you where you spent and you do not want to interrupt your current system, especially if it still allows you to be able to perform and produce as you are supposed to. I think it is just a matter of us opening up to change more than anything."
>
> *Employer Interview 7, 2023 (PGM)*

Other stakeholders cited the lack of awareness as being a barrier to the implementation of new technology, highlighting the importance of increased awareness around 4IR, particularly as it relates to easing fears of retrenchments amongst unskilled employees.

> "[What is limiting adoption of new technologies] currently in my view is that most of the people do not know [about the benefits of technology] and lack awareness of what this new technology entails, how it will impact them and so on. They are quite comfortable in their comfort zone and only think about how retrenchments are coming. So, [the lack of] awareness is a big problem."
>
> *Employer Affiliation Body Interview 2, 2023*

Regarding the threat of job losses, it was noted amongst certain employers that, while job losses are imminent, there is potential within the MMS for employees to be

absorbed in other areas of the MMS value chain to ensure that job losses are minimised.

> "We have introduced a mechanised shaft at the Rustenburg operations. They had to engage with organised labour and obtain their buy in to implement this. They did it in the right manner because in the mining industry, if you do not want trouble, you need to engage with organised labour and make them part of the whole thing. So, if you get their buy in into whatever that you want to implement then everything goes smooth. The only thing that they are concerned about is people losing their jobs. What they are not realising is that some people will lose their current job, but they will be used in other areas through upskilling and retraining."
>
> *Employer Interview 6, 2023 (PGM)*

However, the general sentiment emerging from qualitative consultations indicate that there appears to be caution amongst employers regarding the integration of technology, with employers noting that technology needs to be integrated in a manner that balances employee interests with the potential benefits of technology.

> "At the end of the day to introduce the 4IR you can go with the fact that it is going to have a positive business impact. But at the end of the day if your company's efficiency means that you need to retrench people – it is a step in the wrong direction. It might have a good impact on pockets, but if your communities and people on the ground get impoverished it will have a negative impact on the economy. It means that the unemployment rate in South Africa increases, then it is going to have a negative impact on our economy, and I think that is also the view that our company has. To introduce technology might be good in the short run, but in the long run, if there is no balance between employment and technology it will not have a positive impact in 20 years, because what is going to happen to the people on the ground? You are going to push the pockets of 5% of our economy and the rest is going to be impoverished, and that is just not sustainable. The view that that our company and our management has is for the company to be sustainable. Our communities need to be sustained for our company to be sustainable. We need to employ from the communities as much as possible because if our communities are not sustained and the unemployment rate is high."
>
> *Employer Interview 13, 2023 (Coal Mining)*

8.2 Impact of Changing Technology on Occupations and Skills

While the section above considered the broader impact of changing technology on the MMS, it is important to consider what the implications of changing technology are on occupations and skills within the MMS. As such, this section outlines the impact of changing technology on occupations and skills within the MMS, provides an overview of skills gaps, notes the occupations and skills in demand considering the changing technology within the sector, and explores the occupations, skills, and qualifications that employers and training providers consider to be vulnerable to redundancy.

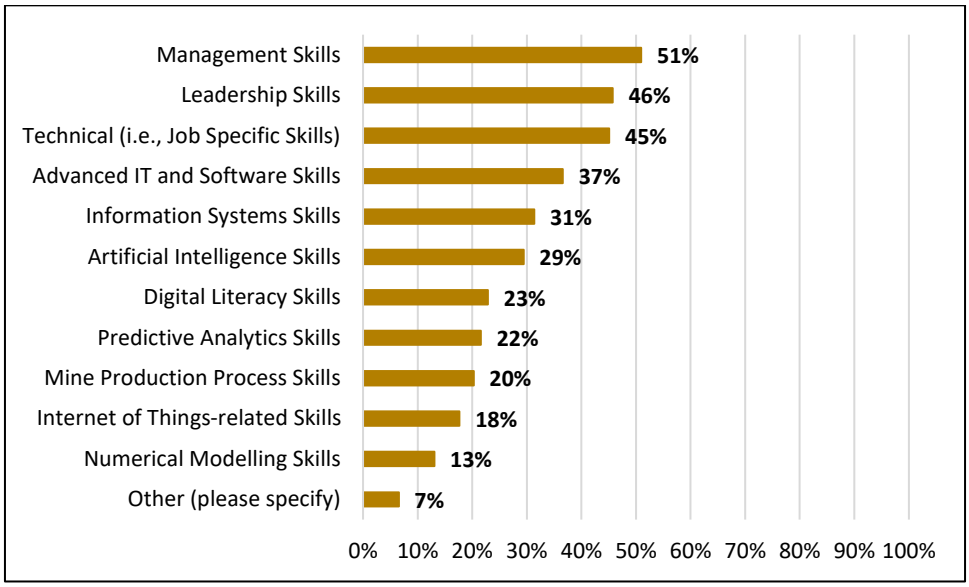
8.2.1 Overview of Skills Gaps

This section provides an overview of the current skills gaps within the MMS, as well as a breakdown of current skills gaps per MMS sub-sector.

8.2.1.1 Current Skills Gaps

As it relates to skills gaps in the sector, stakeholders have indicated that lower-level employees (i.e., plant operators and elementary) will require knowledge and skills in computer literacy, numeracy, and IT skills. Furthermore, management, leadership and supervision, and technical skills have been identified as skills gaps within the sector, as can be seen below.

Figure 8-3: Current MMS Skills Gaps



Source: MQA Skills Demand and Supply Survey, 2023

As can be seen, 51% of employers indicated that there is a gap as it pertains to management skills within their respective organisations. Similarly, 46% of employers cited gaps regarding leadership skills. These results are aligned with views emerging from qualitative data sources, with certain employers indicating that leadership, management, and supervisory skills are lacking within their organisations.

> "I have just done a training needs and skills gap analysis and I think we have got a drastic shortage in properly skilled supervisors, pit supervisors, and foremen on the production side. I think that in the industry, we tend to promote operators that have been with us for a while and that operate well. We take him out of an environment that he is very happy with, and we put him into a supervisory role, which he knows nothing about. I think it is crucial for us to be able to fill that gap and get people who know mining and pit mining for that specific role."
>
> *Employer Interview 33, 2023 (Diamond Processing)*

Employers further indicated that a new subset of management and leadership skills have emerged, with employees occupying these positions being required to manage processes in addition to managing employees.

> "I would say [employees in] managerial or supervisory roles will be greatly impacted by 4IR - it could add more responsibility to their scope. They will have to look at not managing people anymore and managing systems as opposed to managing people."
>
> *Employer Interview 10, 2023 (Coal Mining)*

Furthermore, certain employers highlighted that managers and supervisors may need to adopt a more 'hands-on' approach and may need to change the manner in which they engage with lower-level employees.

> "From the start [of technology implementation], you are going to need to have a more hands-on approach from the supervisors - this is where soft skills come in. So, you need to have supervisors changing the way they deal with people. They are going to have to be more hands-on, talking to the people, assisting them, showing them how it works and coaching them into the new systems."
>
> *Employer 1 Interview, 2023 (Gold Mining)*

The sentiments emerging from fieldwork are also consistent with the literature relating to management and leadership skills, with a perusal of relevant literature identifying management and leadership skills as being key skills gaps amongst 'Technicians', 'Associate Professionals', and 'Managers' (MQA, 2021).

> Inferential Analysis
>
> Chi-Square tests, using a significance level of 0.05, reveal no significant relationship between the size of the organisation and the degree to which the organisation suffers from skills gaps, implying a certain shortages of skills across the market.

8.2.1.2 Skills Gaps per Sub-Sector

While the section above considered the skills gaps within the MMS at an overall level, it is important to explore the MMS skills gaps at a sub-sector level to gain an understanding of which sub-sectors have unique skills gaps as well as to identify skills gaps that are common across several MMS sub-sectors. As such, skills gaps are indicated according to each sub-sector in the table below.

The table is colour coded to indicate which skills gaps are most prevalent within specific sub-sectors. For example, areas coloured in red indicate that between 50% to 100% of employers were of the view that there is a skills gap as it relates to a specific skill for that specific sub-sector.

Table 8-1: Skills Gaps per Mining Sub-Sector[20]

Skills Gaps	Coal Mining	CLAS Mining	Diamond Mining	Diamond Processing	Gold Mining	Jewelry Manufacturing	Other Mining	PGM Mining	Services [illegible]
Leadership Skills	46 %	36 %	75 %	40 %	44 %	23 %	51 %	44 %	50 %
Management Skills	50 %	57 %	75 %	20 %	22 %	69 %	51 %	44 %	54 %
Technical Skills	43 %	71 %	0%	40 %	33 %	38 %	46 %	31 %	58 %
Mine Production Process Skills	29 %	36 %	0%	0%	44 %	0%	21 %	25 %	8%
Advanced IT and Software Skills	36 %	36 %	0%	20 %	33 %	31 %	46 %	38 %	38 %
Numerical Modelling Skills	11 %	7%	0%	40 %	0%	8%	13 %	25 %	19 %
Artificial Intelligence Skills	46 %	14 %	0%	20 %	44 %	31 %	28 %	31 %	23 %
Predictive Analytics Skills	18 %	21 %	25 %	40 %	22 %	8%	18 %	44 %	23 %

[20]

0-20%	21-49%	50%-100%

Skills Gaps	Coal Mining	CLAS Mining	Diamond Mining	Diamond Processing	Gold Mining	Jewelry Manufacturing	Other Mining	PGM Mining	Services Incidental
Internet of Things-related Skills	18 %	21 %	0%	0%	44 %	15 %	18 %	19 %	15 %
Digital Literacy Skills	11 %	7%	25 %	60 %	56 %	23 %	23 %	25 %	27 %
Information Systems Skills	25 %	29 %	25 %	20 %	56 %	8%	46 %	25 %	31 %
Other	7%	7%	0%	20 %	11 %	15 %	3%	0%	8%

Source: MQA Skills Demand and Supply Survey, 2023

As shown above, it appears that there are leadership skills gaps across all sub-sectors. The specific sub-sectors who have challenges in terms of leadership skills gaps include the diamond and other mining sub-sectors, as well as the services incidental to mining sub-sector. Similarly, management skills have been cited as being a key skill gap across all sub-sectors, apart from the diamond processing sub-sector. Technical skills have also been cited as being a key skills gap across all sub-sectors apart from the diamond mining sub-sector. The increased need for technical, job specific skills may be due to the additional skills requirements placed on individuals within occupations such as 'machine operator'; requirements which are closely linked to working with more sophisticated pieces of technology.

> "There will be impact in terms of technical skills requirements; I believe that your operators are going to have to become more mechanically skilled. The operator will not just be the person who operates [the new machine] but will also be the person that has to assist with the maintenance. So, he would need to know a little bit on the technical side and how to use more artisanal based skills. This includes your artisans, such as fitters, boilermakers, who rely on skills on the physical side. On the technical side, they are also going to have to learn to understand the technology involved in the process."
>
> *Employer 1 Interview, 2023 (Gold Mining)*

Other employers shared similar sentiments, noting that machine operators will have to expand their current skillsets to include more technical, machine specific skills to remain relevant in the context of transitioning to mechanised mining operations.

> "We will still need to train artisans to be artisans, but then obviously now we will have to add skills in cases where they work with machines. Let us say it is a robot-like machine. We need to give them skills relating to fault finding, diagnostic skills and so on. Remember, it will be the machine that does the work. So, the artisans will need to programme the machine, which means that we will need to top them up with skills like PLC programming, and things like that. It is not so technical, but it is also technical in a way, but almost in a 'soft skill' manner and not the raw technical skills related to what they are doing. If we top them up with those fault-finding skills, they will then need to use our computers and be computer literate where they can apply that and find the fault to fix that machine."
>
> *Employer Interview 6, 2023 (PGM)*

Regarding other key skills gaps to note, digital literacy skills were cited as being a skill gap for all sub-sectors apart from the coal and CLAS mining sub-sectors, while there are advanced IT and software skills gaps across all MMS sub-sectors apart from diamond mining and diamond processing. The results emerging from the survey data are consistent with insights noted from qualitative data sources, with certain employers noting that a large proportion of machine operators lack the requisite IT skills that are associated with operating virtual machines.

> "Moving from technical machines to virtual machines, we will have to know how the virtual side works, the technology side. With that I am a bit concerned that most operators do not have the IT skills that will be required"
>
> *Employer Interview 1, 2023 (Gold Mining)*

As it pertains to predictive analysis skills, all sub-sectors indicated this to be a key skills gaps within their organisation, apart from organisations within the coal mining, jewellery manufacturing, and other mining sub-sectors. The findings relating to predictive analytics skills align with the literature regarding the latest technological developments internationally, with research identifying predictive maintenance systems, autonomous electronic equipment, and sensor technologies as some of the most prevalent mining technologies in the current context. Predictive maintenance systems, which use sensors, internet connectivity, data processing and other associated technologies, have also provided safety and efficiency benefits to mine operators (Davey, 2023). Therefore, it can be posited that the increased uptake of predictive maintenance technology within specific sub-sectors has resulted in organisations within these sub-sectors requiring skills related to predictive analytics.

While the abovementioned skills gaps appear to be prevalent across most MMS sub-sectors, it is important to understand skills gaps which are linked to specific sub-sectors. As can be seen, for numerical modelling skills, there appears to be significant gaps within the PGM and diamond processing sub-sectors only. This could be

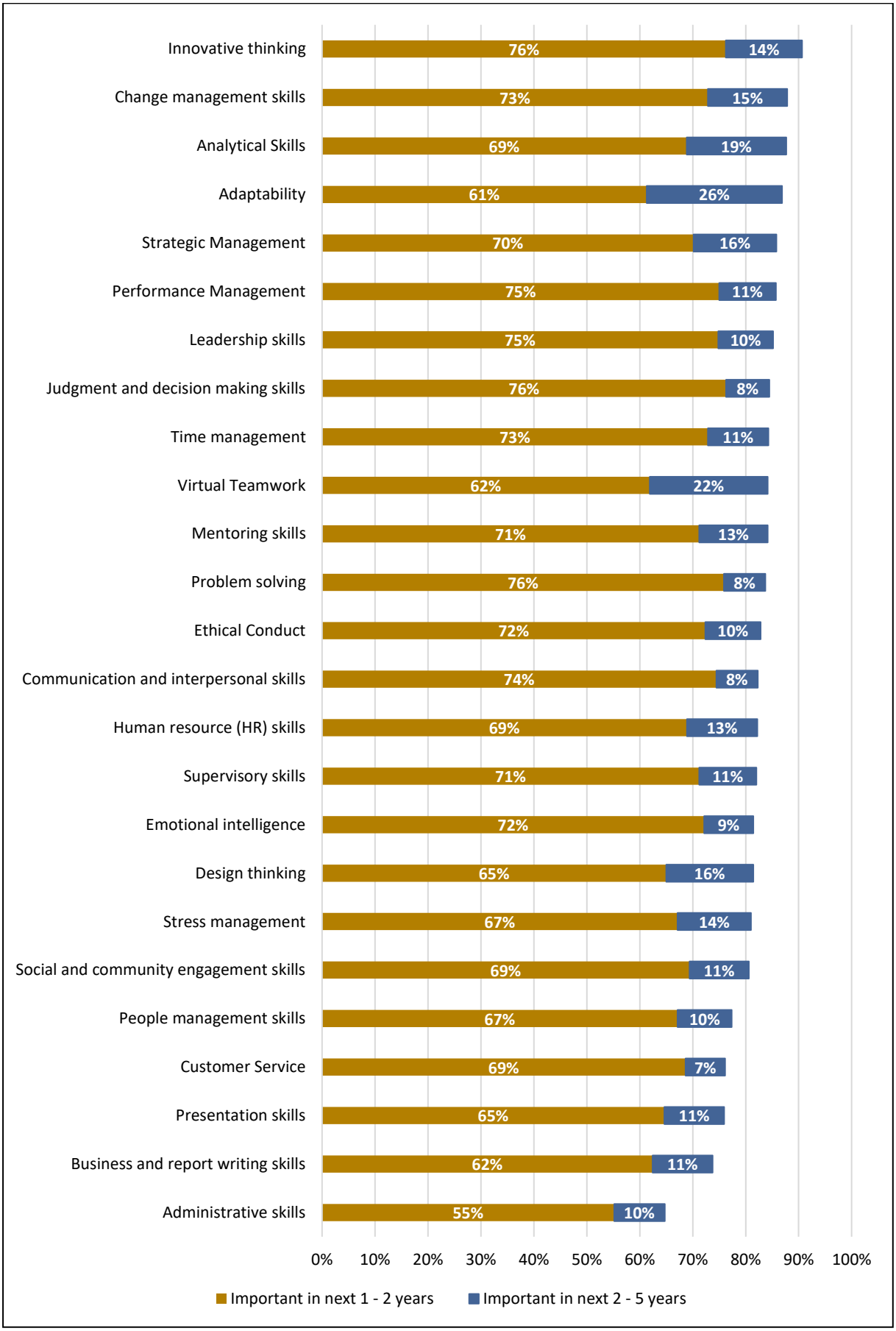
reflective of the increased need for these specific skills within these unique mining contexts. For example, within the context of an underground room and pillar operation aiming to extract PGMs, there may be an increased need for numerical modelling skills. Within this context, numerical models may assist in: understanding and/or quantifying factors such as stress redistribution of pillars during the retreat mining process[21]; conducting stability analyses to simulate the behaviour of pillars under various conditions; optimising pillar design by considering different ore body geometrics, rock properties, and stress conditions; as well as providing more accurate predictions of roof stability, all factors which can positively contribute to mine worker safety within room and pillar contexts. Similarly, within the diamond processing context, numerical modelling may be particularly important as it pertains to optimising the various stages of diamond processing such as crushing, grinding, and sorting. Other sub-sector specific skills gaps identified through analysis of the quantitative data include internet-of-things related skills, with only the CLAS and gold mining sub-sectors citing this as being a skills gap.

8.3 Skills in Demand

While the data shown above outlines the current context regarding skills gaps, it is important to consider what the soft and technical skills requirements may be in the immediate to short-term future to identify skills to prioritise in terms of the provision of support from a skills development perspective. These results are shown below.

[21] Retreat mining is a mining method that is most common within underground room and pillar mines. Engaging in the process of retreat mining creates an unstable working environment for mine workers given that pillars, which are initially left in place to provide support for the roof of the mine, are removed (Dean-Pelikan, 2021).

Figure 8-4: Soft Skills in Demand – Short vs. Long Term



Source: MQA Skills Demand and Supply Survey, 2023

As can be seen, from a soft skills perspective, the skills that will become increasingly important in the immediate future include judgement and decision making (76%), innovative thinking (76%), problem solving (76%) and leadership (75%). These findings correlate with sentiments emerging from qualitative data, with several employers citing the increasing importance of leadership and change management skills, particularly as organisations attempt to integrate more sophisticated technologies in their operations.

> "Change management skills are going to become important - this is the ability to explain to workers how [new technology] can be used and to make people acceptable towards it, otherwise they would resist the change. Leadership skills will also become important because supervisors will now have to consider how to manage new technologies and how to manage the employees using the new technology."
>
> *Employer Interview 18, 2023 (Diamond Mining)*

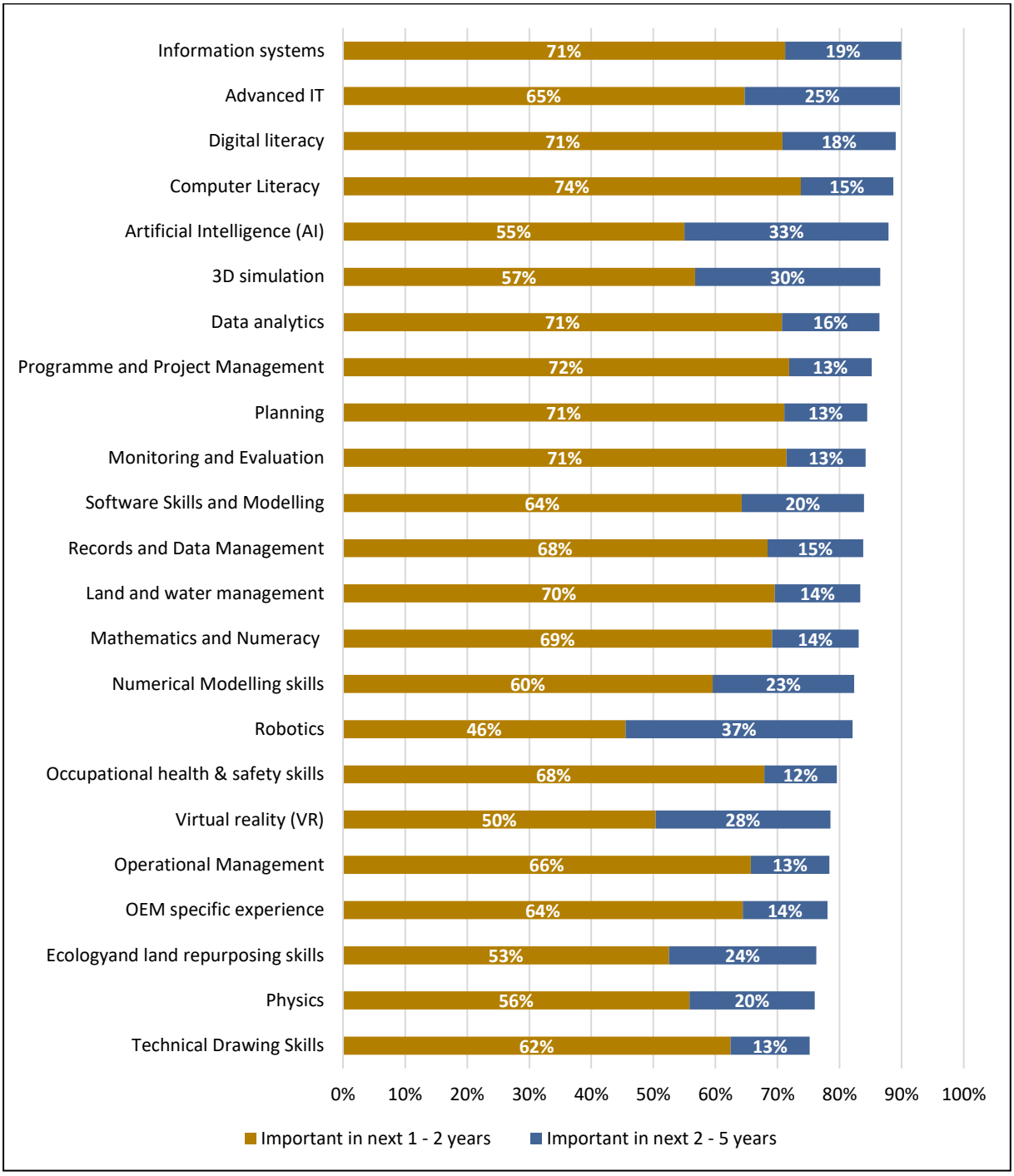
This was corroborated in other employer consultations, with employers indicating that equipping managers with change management skills are critical in terms of ensuring that employees who work under said managers are mentally prepared for any form of change.

> "Most mining managers need to be given training for change management so that they can make people aware well ahead of time so that employees can mentally prepare themselves for the change in the organisation."
>
> *Employer Interview 30, 2023 (Services Incidental to Mining)*

Furthermore, stakeholders have also cited "adaptability" as being more important in the two-to-five-year time frame. This may reinforce the notion that changing technology will bring about more and more changes to the ways-of-work. Some stakeholders indicated that some of these changes are impossible to predict and employers and employees should be equipped with the skills required to adapt and not just technical skills (some of which do not exist yet). This is an important consideration when responding to skills needs in any sector, within the context of changing technology.

In addition to soft skills, employers were also asked to provide input on technical skills required within the MMS in the immediate to short term future. These results are shown below.

Figure 8-5: Technical Skills in Demand – Short vs. Long Term



Source: MQA Skills Demand and Supply Survey, 2023

As can be seen, employers have indicated that technical skills related to computer literacy (74%), data analytics (71%), and digital literacy (71%) will increase in demand in the immediate to short term future. These results may be reflective of the concerns cited by employers as it relates to upskilling their employees, with computer and digital literacy being a key prerequisite in terms of participating in e-learning initiatives. Furthermore, as the MMS moves towards mechanisation, which is underpinned by the increased uptake of more sophisticated technologies across the mineral extraction

value chain, the need for employees with computer and digital literacy skills becomes apparent. The lack of computer and digital literacy skills amongst current MMS employees is a challenge that is well documented in the literature, and one that is an ongoing concern for the broader MMS as it relates to upskilling employees. This challenge is further compounded by a lack of basic numeracy and literacy skills, which further impedes on employers' ability to upskill their employees.

Regarding other skills in demand, technical skills related to project management (72%) and planning (71%) have also been cited as skills that will become important in the immediate future. This correlates with employer sentiments cited in qualitative consultations, with certain employers noting change management as well as project management skills as being key to ensuring that new technology is integrated in the least disruptive manner.

> "In terms of skill sets, firstly, one, in terms of managing change. I think people that will be good in facilitating change management processes, then project management. Project management has always been there, but I think the thing is, in the industry we have not been good at managing the associated change. We have seen some companies starting to employ this at corporate level, but I can foresee in future going to operation level, where they bring in so-called change management principles, or operational readiness positions. Now, these are soft skills that bridges between the project management team and the end users. The project management team will facilitate the project, deliver it, hand it over to the end users, but what has been picked up, there is a gap where you need some form of a facilitator, coordinator, between the project team and the end users."
>
> *Employer Affiliation Body Interview 1, 2023*

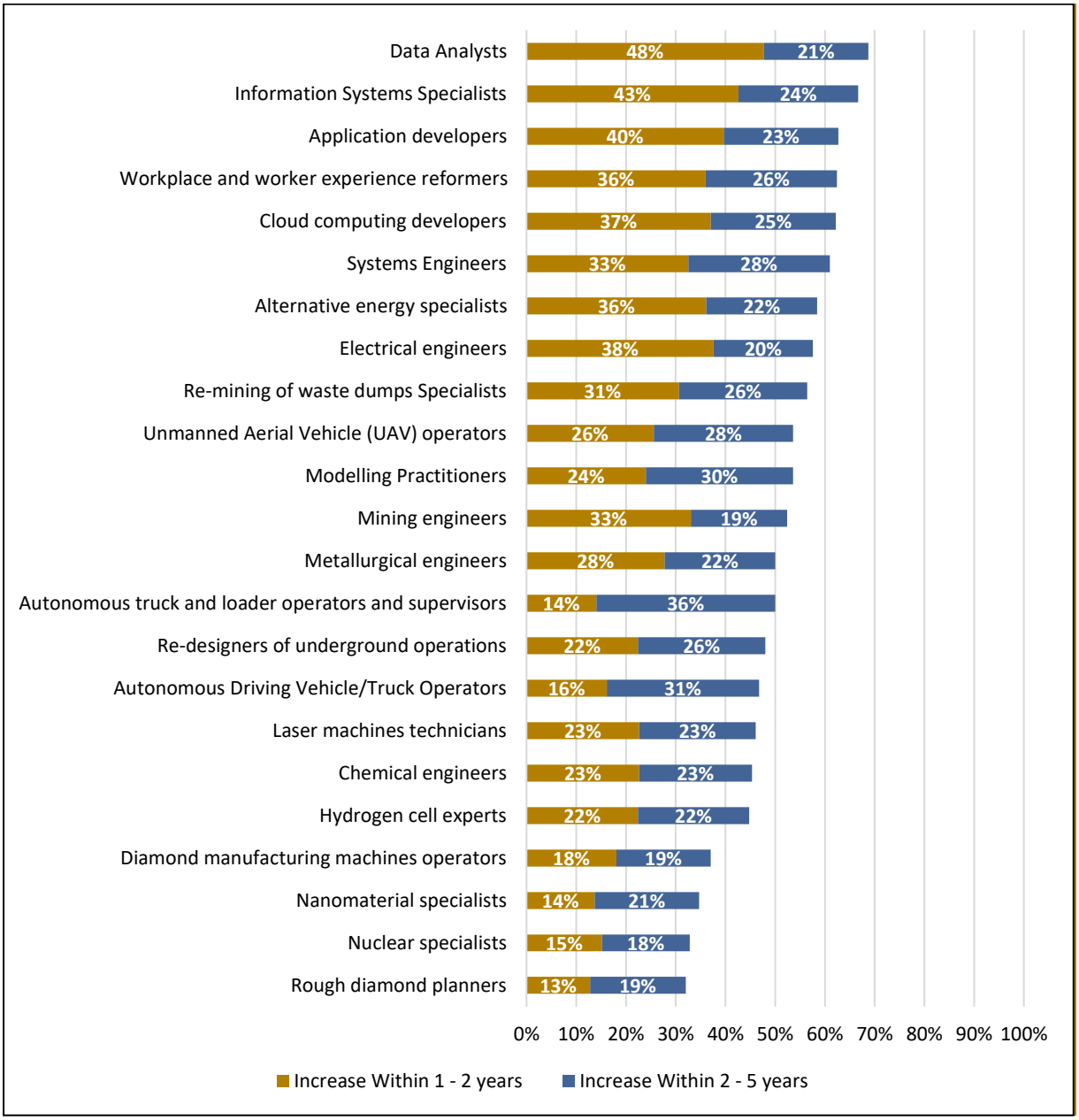
Data analytic skills (71%) were also cited as skills that will become increasingly important in the immediate/short-term future. This aligned with views emerging from qualitative consultations, with certain employers noting that individuals in supervisory positions will require skills related to the integration and consolidation of multiple data sources, further noting that supervisors may be required to analyse and understand large volumes of data due to the use of more sophisticated software and technologies.

> "Then I think the production supervisors, or technical supervisors, will need a skill set of integrating data, because with all these 4IR technologies you get a lot of data that is generated through reports. Analysing those reports and making sense out of them is a big challenge because you get isolated reports, and how to integrate that information, that is a big challenge. One of the things we have seen coming up in skill sets is integrators. We have a few different systems standalones, monitoring various aspects of the business, whether it is technical, HR, finance, or safety. As end users, we get bogged down with a lot of reports, even just within machinery or processes you might have five reports reporting different aspects of a process or a system. Which report do we give attention first? What we have seen coming up now is that some of these IT companies, they have now come with a layer that integrates these various reports and give you an exception report."
>
> *Employer Affiliation Body Interview 1, 2023*

8.4 Occupations in Demand

While it is important to note the current context in terms of skills gaps and skills in demand, it is equally important to consider the occupations for which demand is anticipated to increase in the immediate to short-term future.[22] These results are shown below.

Figure 8-6: Occupations in Demand as a Result of 4IR



Source: Skills Demand and Supply Survey, 2023

As can be seen, the top occupations that stakeholders believe are likely to become more in demand in the short-term considering the changing technology within the sector are:

[22] Within the context of this report, immediate to short term future refers to a 1–2-year timeframe.

- Data analysts (48%);
- Information systems specialists (43%);
- Application developers (40%); and
- Workplace and Worker Experience Reformers (36%).

The findings relating to increased demand for data analysts and information systems specialists align with the insights from the literature, with employers citing data management as being key for their organisation to make informed and data led decisions, highlighting the need for individuals in data and/or systems related roles (PwC, 2021). This is also consistent with sentiments emerging from qualitative data, with several employers noting increased demand for data analysts and systems specialists.

> "The others we have seen coming up is this data analyst because with automation or 4IR there's a lot of data that comes around. We've seen a trend in the industry of mining houses creating positions, so-called data analysts."
>
> *Employer Affiliation Body Interview 1, 2023*

In addition to data and systems related roles, an increase in demand is also expected for workplace and worker experience reformers (i.e., change management specialists), due to their envisioned role in guiding organisations and their employees through the inevitable changes that will be brought about by the 4IR, including the implementation of new systems, technologies, and processes.

> "There will be some form of resistance [to the adoption of 4IR-related technologies] that will have to be addressed [by] change management [specialists] because the employees need to be reassured that it would be for the better."
>
> *Employer Interview 18, 2023 (Diamond Mining)*

8.5 Redundant Occupations and Skills

Considering the changing technology within the global mining sector, it is important to understand how occupations and the skills required for specific occupations may change due to the use of more sophisticated technology. The introduction of new technologies has been associated with the risks of decreased employment opportunities at mines and the redundancy of traditional skills. (Cawood, 2020). It is therefore important to note the occupations and skills that have and may become redundant as a result of the changing technology within the MMS.

The relatively low adoption of changing technologies within the MMS has meant that for the most part, occupations have remained relevant. While the risk of redundancy does not appear to be a cause for concern for workers in the sector for the foreseeable future, consulted employers have indicated that changing technologies will have an impact on the number of individuals that mining companies employ. As seen below,

consulted employers have indicated that the introduction of changing technologies will have an impact on the number of employees required on mechanised mines.

> "It will have an impact on employees. Mechanised mines will have half the number of employees you usually have on conventional mines. There will be a negative impact for employment but a positive impact for safety."
>
> *Employer Interview 8, 2023 (PGM)*

> "The problem with going more of a technological sense and automating the system is that your resource, being employees, are decreasing. Where in the past we needed about, let's say, for example, 30 dumper truck operators, we only need 10 of them now."
>
> *Employer Interview 19, 2023 (Diamond Processing)*

In addition to changing technologies having an impact on the number of workers required, stakeholders have indicated that occupations will be required to have additional competencies to be able to operate in a more technologically advanced sector. Some of these additional competencies include:

- Digital Literacy Skills
- Managerial and Supervisory Skills
- Problem-Solving and Critical Thinking Skills
- Ongoing Learning and Mentoring and Coaching Skills

Below are the sentiments of a consulted employer regarding the impact of changing technologies and the importance of being multi-skilled.

> It's just one small part of the operation. We have looked at creating more multi-operators to make them more competent to do more than one thing at a time. I am not sure what the industry is doing but it's something that might help us close our gap."
>
> *Employer Interview 17, 2023 (Diamond Mining)*

While the general view amongst consulted employers is that there will not be any redundant occupations, there are a few instances where employers have noted that occupations and skills have become redundant.

> "In terms of roles being redundant, for example, in the drawing office we used to have several people who would check the drawings. But now we have a system that does that and all you need is one person who needs to approve what the system has checked."
>
> *Employer Interview 24, 2023 (Services Incidental to Mining)*

In addition to the above, consulted stakeholders in the sector have also noted that the below occupations have become redundant in the past year as a result of changing technology:

- Administration and Office support
- Locomotive Drivers
- Engineering Assistants
- Exploration Assistant
- Machine Operator

Furthermore, from a skills perspective, consulted stakeholders have indicated that the below skills have become redundant in the past year as a result of changing technology:

- Administrative Work
- Cuttlefish Bone Casting
- Data Capturing
- Switchboard Skills
- Hand Manufacturing

Consulted stakeholders have also indicated that the most significant changes in skills requirements will be seen in the "machine operator" occupation.

> "I don't think redundancy will come into play, upscaling in the mechanised world will happen. You will get your more improved operators in a conventional [mine]. If you talk conventional you will always have your labourers and then from there on the career path development will be the cost."
>
> *Employer Interview 5, 2023 (PGM)*

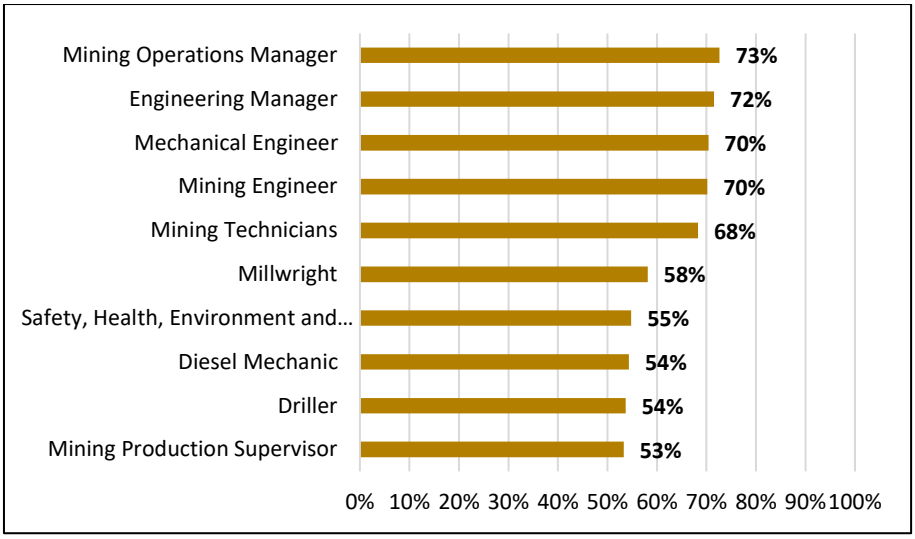
The assertion that in addition to job losses, the introduction of new technologies will lead to redundant occupations is based on the analysis of occupations as they are currently (Mining Industry Human Resources Council, 2020). However, it appears that occupations will, for the most part, evolve in response to the integration of new technologies and the competencies required to make use of said technologies (Mining Industry Human Resources Council, 2020).

8.6 Overview of HTFVs and Occupational Shortages

The figure below provides an overview of HTFVs within the broader MMS, as reported by employers. [23]

Figure 8-7: HTFVs in the MMS

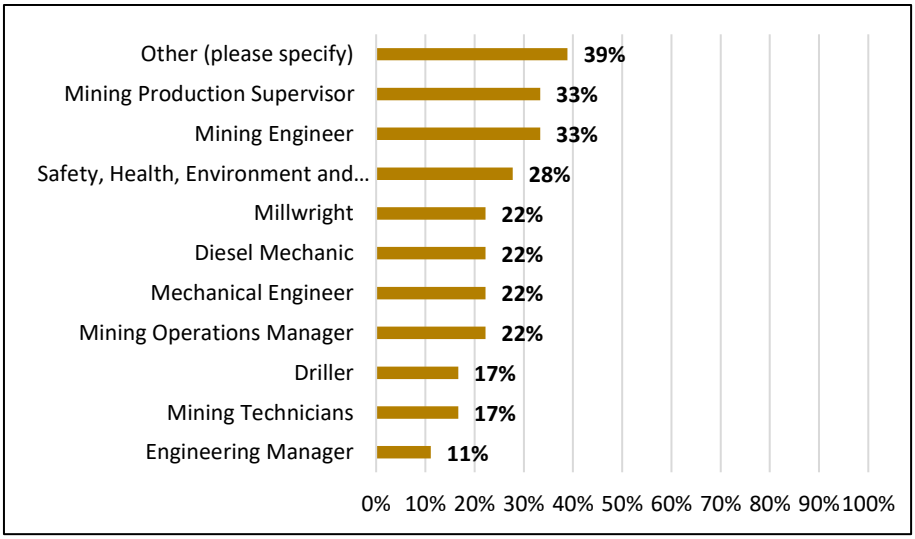
[23] Reference to 'employers' within the context of this report refers to representatives within MMS organisations. These representatives occupied a range of different roles within their organisations such as Human Resource Development Managers, Learning and Development Managers, Business Owners, Training Superintendents, Talent Management Specialists, Business Directors, Compliance Managers, Human Resource Consultants, Operations Directors, and Skills Development Facilitators.



Source: Skills Demand and Supply Survey, 2023

As shown above, overall, 73% of employers indicated that the mining operations manager occupation is hard to fill. Similarly, 72% noted that engineering manager roles are hard to fill. Regarding the other notable occupations considered to be hard to fill, employers noted that mechanical engineer (70%), mining engineer (70%) and mining technician (68%) roles are hard to fill within the MMS. These results align to the view of training providers within the MMS as it relates to occupational shortages, with 33% of training providers citing mining production supervisor and mining engineer occupations as hard to fill, as can be seen below.

Figure 8-8: Occupational Shortages – Training Providers



Source: Skills Demand and Supply Survey – Training Providers, 2023

In addition to citing mining production supervisor and mining engineer occupational shortages, 28% of training providers noted SHE&Q practitioners as a major occupational shortage, while 22% indicated that there are major occupational shortages within the millwright, diesel mechanic, mechanical engineer, and mining operations manager occupations. Regarding 'other' occupational shortages, 39% of

training providers cited shortages for plant manager, refractory mason, metallurgist, and process plant manager occupations.

Analysis of sub-sector specific data indicates that MMS employers face challenges in filling engineering related roles across most MMS sub-sectors. Specific sub-sector nuances included:

- The diamond mining sub-sector, which cited SHE&Q practitioners, diamond cutters and diamond polishers as being hard to fill, in addition to engineering related roles;
- The jewellery manufacturing sub-sector, which cited craftsman, goldsmith, and bench worker occupations as being hard to fill in addition to engineering related roles;
- The services incidental to mining sub-sector, which cited the rock-drill operator occupation as being hard to fill; and
- The PGM sub-sector, which cited drill rig operator, electrician, diesel mechanic, and trackless machinery operator occupations as hard to fill, in addition to engineering related roles.

Regarding the reasons underpinning the inability to fill engineering positions, MMS employers across all sub-sectors noted three specific challenges namely: a lack of qualified candidates; a lack of suitably qualified candidates within specific geographies, and a lack of experienced candidates. This suggests that organisations (across most sub-sectors) attempting to fill these roles have challenges finding individuals with suitable qualifications within their specific geographies. A possible reason for this may be the location of these organisations. This view is supported by the literature, which indicates that mining companies, across all sub-sectors, struggle to attract talent to work and live at mine sites with some mining companies opting for remote support from urban locations with mines having to consider paying a premium to have said skills in the remote locations that mines are typically found in (Ramdoo, et al., 2021). This indicates a need to develop relevant skillsets within the communities where mines are located, to build a pipeline of future skills at mine sites. Furthermore, insights from interviews with employers revealed other challenges contributing to engineering occupations being hard to fill, noting that engineers typically receive better remuneration in other industries, meaning that working in the mining industry is a less attractive option for these individuals.

The data also flagged a lack of qualifications as being a reason contributing to the inability to fill engineering related positions, suggesting supply side issues. This is also consistent with the literature, with statistics indicating a consistent decline in the number of enrolments for MMS related qualifications[24] between 2017 and 2021 (DHET,

[24] MMS related qualifications include:

- Chemical Engineering
- Electrical, Electronics and Communications Engineering
- Mechanical and Mechatronic Engineering

2023). In addition to declining levels of enrolment, there have also been declines in the number of graduates for MMS related qualifications in the same period. This is perhaps indicative that more emphasis needs to be placed by the MQA to encourage individuals at high school level to pursue MMS related qualifications, alternatively, more emphasis can be placed on communicating the various career paths that are available within the MMS. Overall, it appears that necessary steps need to be taken to redefine the image of the MMS to attract individuals to the sector.

Regarding the lack of engineering graduates, it can be deduced that this is due to broader deficiencies in the basic education system, which fails to equip learners at the grassroots level with a strong foundation as it pertains to Science, Technology, Engineering, and Maths ("STEM") subjects (Pols, 2019) This deficiency has a domino effect on both the number of enrolments for engineering related qualifications as well as graduation rates. Further insights from research suggests that low success rate in Science, Technology, Engineering, and Maths ("STEM") related subjects at high school level are key contributors to the limited supply of engineering graduates within the South African context (Akinshipe, et al., 2019). It is therefore evident that there are challenges across the education pipeline which contribute to the limited supply of engineers in the South African context. Within the MMS context, when considering the limited supply of engineers generally, together with the fact that that the MMS is often competing with other sectors which are perceived to be more attractive to engineering graduates, it is evident as to why there are engineering related occupational shortages across most MMS sub-sectors.

A lack of experienced candidates was also cited as a reason contributing to the inability to fill engineering related positions. This also suggests supply side challenges, particularly from the perspective of ensuring that graduates, or individuals close to graduating, have adequate workplace experience. Research suggests that the higher education system does not adequately prepare learners in terms of the skills required for work, which alludes to a broader, more systemic issue that is contributing to the lack of workplace experience amongst candidates.

Inferential Analysis

Chi-Square tests, using a significance level of 0.05, reveal no significant relationship between the size of the organisation and the degree to which the organisation experiences HTFVs. However, there does appear to be a slightly stronger relationship as it pertains to managerial occupations (specifically Engineering Manager) than for artisans. This aligns to the existing body of knowledge that occupations such as an Engineering Manager would be able to command higher salaries in the market that smaller organisations would have difficulty matching.

8.7 Reasons for HTFVs

- Metallurgical Engineering
- Mining and Mineral Engineering
- Geology and Earth Sciences/Geosciences

While the section above considered HTFV's at an overall level, across MMS sub-sectors, this section provides an overview of HTFVs per MMS sub-sector. These HTFVs were identified by analysing the inputs gathered from stakeholders through surveys, interviews and focus groups. This section also provides insight on the reasons for the occupations or vacancies being hard to fill.

8.7.1 CLAS

The table below shows the occupations or vacancies considered to be hard to fill for employers within the CLAS sub-sector. The table also provides insight into the reasons contributing to these occupations or vacancies being hard to fill.

Table 8-2: Reasons for HTFVs – CLAS Mining

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Qualified Candidates	Lack of Experienced
Engineering Manager	10%	50%	10%	30%	0%	0%	80%	60%
Mining Operations Manager	17%	42%	8%	17%	0%	8%	67%	42%
Mining Engineer	18%	36%	9%	18%	0%	9%	73%	36%
Mechanical Engineer	20%	30%	10%	20%	0%	10%	80%	40%
Mining Technician	22%	33%	11%	0%	11%	11%	67%	33%
Millwright	33%	22%	11%	11%	0%	0%	44%	33%

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Qualified Candidates	Lack of Experienced
SHE&Q Practitioner	36%	45%	9%	9%	9%	9%	18%	36%
Mining Production Supervisor	36%	18%	0%	0%	0%	0%	27%	45%
Driller	44%	22%	0%	0%	0%	0%	33%	22%
Diesel Mechanic	50%	17%	0%	0%	0%	0%	33%	33%

Source: MQA Skills Demand and Supply Survey, 2023

Analysis of the results for the CLAS sub-sector indicate that engineering manager, mining operations manager and mining engineer occupations are the hardest to fill. Further analysis of the quantitative data reveals that the most common challenges facing employers as they relate to filling these positions include a lack of qualifications, limited pools of suitably qualified candidates within the geographies that CLAS organisations are situated, as well as a lack of experienced candidates.

8.7.2 Coal Mining

The table below shows the occupations or vacancies considered to be hard to fill for employers within the coal mining sub-sector. The table also provides insight into the reasons contributing to these occupations or vacancies being hard to fill.

Table 8-3: Reasons for HTFVs – Coal Mining

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to Develop	Lack of Interest from Employees	Limited Pool of Qualified	Lack of
Mining Operations Manager	30%	37%	19%	15%	15%	7%	26%	30%
Mechanical Engineer	32%	18%	11%	4%	11%	0%	32%	25%
Engineering Manager	33%	22%	11%	4%	22%	7%	33%	30%
Mining Engineer	37%	11%	11%	4%	7%	4%	26%	37%
Mining Technician	40%	12%	12%	16%	8%	4%	12%	28%
Millwright	48%	19%	15%	7%	15%	4%	19%	22%
Driller	52%	22%	22%	11%	11%	0%	7%	19%
SHE&Q Practitioner	56%	11%	11%	11%	4%	7%	11%	19%
Diesel Mechanic	56%	15%	15%	0%	11%	4%	15%	11%
Mining Production	71%	17%	8%	4%	8%	0%	8%	13%

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to Develop	Lack of Interest from Employees	Limited Pool of Qualified Candidates	Lack of Experienced
Supervisor								

Source: MQA Skills Demand and Supply Survey, 2023

Analysis of the results for the coal mining sub-sector indicates that engineering manager, mining operations manager and mechanical engineer occupations are the hardest to fill. Further analysis of the quantitative data reveals that the most common challenges facing employers as they relate to filling these positions include a lack of qualifications, limited pools of suitably qualified candidates within the geographies that coal mining organisations are situated, as well as a lack of experienced candidates. The lack of funding to develop skills was also cited as a reason contributing to the engineering manager occupation being hard to fill within the coal mining context.

8.7.3 Diamond Mining

The table below shows the occupations or vacancies considered to be hard to fill for employers within the diamond mining sub-sector. The table also provides insight into the reasons contributing to these occupations or vacancies being hard to fill.

Table 8-4: Reasons for HTFVs - Diamond Mining

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool off Qualified Candidates	Lack of Experienced
Engineering Manager	25%	25%	25%	0%	25%	0%	50%	50%
Mechanical Engineer	25%	25%	25%	0%	25%	0%	50%	50%

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool off Qualified Candidates	Lack of Experienced
SHE&Q Practitioner	25%	25%	25%	25%	25%	25%	75%	25%
Mining Engineer	67%	0%	0%	0%	0%	0%	33%	0%
Mining Technician	75%	25%	25%	25%	25%	25%	25%	25%
Millwright	75%	25%	25%	25%	25%	25%	25%	25%
Diesel Mechanic	75%	25%	25%	0%	25%	0%	25%	25%
Mining Operations Manager	100%	0%	0%	0%	0%	0%	0%	0%
Mining Production Supervisor	100%	0%	0%	0%	0%	0%	0%	0%
Driller	100%	0%	0%	0%	0%	0%	0%	0%

Source: MQA Skills Demand and Supply Survey, 2023

Analysis of the results for the diamond mining sub-sector indicates that engineering manager, mechanical engineer, and SHE&Q practitioner occupations are the hardest to fill. Employers also revealed in qualitative consultations that diamond cutters and diamond polishers are occupations that are hard to fill within the diamond mining context.

> "I would say a couple of gaps I have identified are diamond cutters and diamond polishers."
>
> *Employer Interview 20, 2023 (Diamond Processing)Employer Interview 20, 2023 (Diamond Mining)*

Further analysis of the quantitative data reveals that the most common challenge facing employers as it relates to filling these positions is that there are limited pools of suitably qualified candidates within the geographies that diamond mining organisations are situated. This was also noted in the qualitative data, with employers indicating that geographical location is a key factor impacting on employers' ability to fill vacancies.

> "Gaps are also dependant of geographical location, for example if you are looking for a diamond cutter in an area where you are not aware of skills providers then you will not easily get fill that position."
>
> *Employer Interview 20, 2023 (Diamond Processing)*

8.7.4 Diamond Processing

The table below shows the occupations or vacancies considered to be hard to fill for employers within the diamond processing sub-sector. The table also provides insight into the reasons contributing to these occupations or vacancies being hard to fill.

Table 8-5: Reasons for HTFVs - Diamond Processing

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Suitably Qualified	Lack of Experienced
Mining Operations Manager	0%	33%	0%	0%	0%	0%	33%	33%
Mechanical Engineer	0%	33%	0%	0%	0%	0%	33%	33%
Mining Production Supervisor	0%	0%	0%	33%	0%	0%	33%	33%

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Suitably	Lack of Experienced
Mining Technician	0%	0%	0%	0%	33	33%		33%
Mining Engineer	0%	0%	0%	33%	0%	0%	33%	33%
Millwright	25%	25%	0%	0%	0%	25%	25%	25%
SHE&Q Practitioner	25%	0%	0%	0%	25%	0%	25%	25%
Engineering Manager	33%	0%	0%	0%	0%	0%	33%	33%
Diesel Mechanic	33%	0%	0%	0%	0%	0%	33%	33%
Driller	33%	0%	0%	0%	0%	0%	33%	33%

Source: MQA Skills Demand and Supply Survey, 2023

Analysis of the results for the diamond processing sub-sector indicates that mining operations manager, mechanical engineer, and mining production supervisor occupations are hardest to fill. Further analysis of the quantitative data reveals that the most common challenges facing employers as they relate to filling these positions include a lack of qualifications, limited pools of suitably qualified candidates within the geographies that diamond processing organisations are situated, as well as a lack of experienced candidates. The lack of awareness of skills relevant to individual organisations was also cited as a reason contributing to the mining production supervisor occupation being hard to fill within the diamond processing context.

8.7.5 Gold Mining

The table below shows the occupations or vacancies considered to be hard to fill for employers within the gold sub-sector. The table also provides insight into the reasons contributing to these occupations or vacancies being hard to fill.

Table 8-6: Reasons for HTFVs - Gold Mining

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Qualified	Lack of Experienced
Engineering Manager	11%	44%	0%	0%	33%	11%	11%	33%
Mechanical Engineer	13%	13%	0%	0%	13%	13%	38%	38%
Mining Operations Manager	22%	22%	11%	0%	11%	11%	33%	33%
Mining Engineer	22%	33%	0%	11%	22%	0%	11%	22%
Mining Technician	22%	22%	0%	11%	11%	11%	22%	22%
SHE&Q Practitioner	33%	33%	11%	0%	22%	0%	22%	22%
Diesel Mechanic	33%	11%	0%	0%	22%	11%	11%	33%
Millwright	38%	38%	0%	0%	13%	13%	0%	13%
Mining Production	50%	13%	0%	0%	13%	0%	25%	0%

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Qualified	Lack of Experienced
Supervisor								
Driller	56%	0%	0%	0%	11%	0%	0%	33%

Source: MQA Skills Demand and Supply Survey, 2023

Analysis of the results for the gold mining sub-sector indicates that engineering manager and mechanical engineer occupations are the hardest to fill. Further analysis of the quantitative data reveals that the most common challenges facing employers as they relate to filling these positions include a lack of qualifications, limited pools of suitably qualified candidates within the geographies that gold mining organisations are situated, as well as a lack of experienced candidates. The lack of funding to develop skills was also cited as a reason contributing to the engineering manager occupation being hard to fill within the gold mining context.

8.7.6 Jewellery Manufacturing

The table below shows the occupations or vacancies considered to be hard to fill for employers within the jewellery manufacturing sub-sector. The table also provides insight into the reasons contributing to these occupations or vacancies being hard to fill.

Table 8-7: Reasons for HTFVs - Jewellery Manufacturing

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Suitably Qualified	Lack of Experienced
Engineering Manager	33%	0%	11%	0%	0%	0%	11%	44%
Mechanical Engineer	33%	0%	17%	0%	17%	0%	0%	33%

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Suitably Qualified	Lack of Experienced
Mining Engineer	33%	0%	17%	17%	0%	0%	0%	33%
Mining Technician	33%	0%	17%	17%	0%	0%	17%	17%
Mining Production Supervisor	33%	0%	17%	17%	0%	17%	17%	0%
Diesel Mechanic	33%	0%	17%	17%	0%	33%	0%	0%
SHE&Q Practitioner	40%	0%	40%	0%	30%	10%	0%	10%
Mining Operations Manager	50%	0%	17%	0%	0%	17%	0%	17%
Driller	50%	0%	17%	17%	0%	17%	0%	0%
Millwright	50%	0%	17%	17%	0%	17%	0%	0%

Source: MQA Skills Demand and Supply Survey, 2023

Analysis of the results for the jewellery manufacturing sub-sector indicates that engineering manager, mechanical engineer, mining engineer, mining technician, mining production supervisor and diesel mechanic occupations are the hardest to fill. Further analysis of the quantitative data reveals that the most common challenge facing employers as it relates to filling these positions includes a lack of experienced candidates. Additionally, analysis of the qualitative data revealed that, within the

jewellery manufacturing sub-sector, occupations such as craftsman, goldsmith and bench workers are hard to fill.

> "Craftsman, goldsmith, and bench workers are lacking. There does not seem to be a flow of newcomers in the market because it does not seem as attractive anymore. I think it is a dying industry. We have lost a lot of clients in the Western Cape; I am not sure what it is like in Gauteng. The number of manufacturers that are involved in the jewellery sector has reduced. I am not sure what technologies apply in the east, but markets started dwindling many years ago before 4IR. Competitiveness is not the same."
>
> *Employer Interview 21, 2023 (Jewellery Manufacturing)*

8.7.7 Other Mining

The table below shows the occupations or vacancies considered to be hard to fill for employers within the other mining sub-sector. The table also provides insight into the reasons contributing to these occupations or vacancies being hard to fill.

Table 8-8: Reasons for HTFVs - Other Mining

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Qualified Candidates	Lack of Experienced
Mining Operations Manager	21%	18%	12%	21%	15%	6%	35%	24%
Engineering Manager	23%	37%	9%	6%	11%	3%	26%	37%
Mining Engineer	25%	19%	6%	13%	13%	6%	31%	31%
Mining Technician	27%	18%	6%	6%	18%	12%	18%	30%
Mechanical Engineer	33%	15%	12%	9%	18%	3%	27%	27%
Driller	36%	24%	9%	18%	9%	12%	6%	21%

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Qualified Candidates	Lack of Experienced
Mining Production Supervisor	38%	15%	9%	9%	9%	12%	21%	29%
Millwright	39%	25%	11%	6%	14%	8%	19%	14%
Diesel Mechanic	44%	25%	9%	6%	16%	6%	16%	22%
SHE&Q Practitioner	47%	24%	15%	26%	12%	3%	15%	21%

Source: MQA Skills Demand and Supply Survey, 2023

Analysis of the results for the other mining sub-sector indicates that mining operations manager and engineering manager occupations are the hardest to fill. Further analysis of the quantitative data reveals that the most common challenges facing employers as they relate to filling these positions include a lack of experienced candidates, a lack of qualifications as well as limited pools of suitably qualified candidates in the geographies that other mining organisations are located. Additionally, analysis of the qualitative data revealed that, within the other mining sub-sector, the medium and short term mine planner occupations are hard to fill. Employers also highlighted geographical challenges which compound the difficulties faced as it pertains to filling these vacancies.

> "We have medium- and short-term planners, these are the positions that we are struggling to fill. We had a medium-term planner last year but she recently resigned, so now we outsource. Moolman is running the operations side of the mine, so they also have their own planners that we can use from time to time. We are unable to fill these vacancies because it is a scarce skill and we are in a remote location, where people find the environment to be hard to adjust to. Usually, people we get for these positions come from other provinces like Mpumalanga. It would be difficult to have planners who are not physically on the mine because the position is more focused on operations."
>
> *Employer Interview 32, 2023 (PGM)*

8.7.8 PGM Mining

The table below shows the occupations or vacancies considered to be hard to fill for employers within the PGM mining sub-sector. The table also provides insight into the reasons contributing to these occupations or vacancies being hard to fill.

Table 8-9: Reasons for HTFVs – PGM Mining

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Suitably	Lack of Experienced
Mining Operations Manager	19%	19%	6%	0%	6%	6%	56%	31%
Engineering Manager	25%	31%	13%	6%	6%	13%	44%	31%
Mechanical Engineer	25%	19%	19%	0%	13%	6%	25%	31%
Mining Technician	25%	25%	25%	0%	13%	0%	19%	38%
Mining Engineer	31%	13%	6%	0%	6%	13%	44%	25%
Millwright	31%	19%	13%	0%	6%	13%	19%	38%
Driller	38%	0%	13%	6%	6%	6%	31%	31%
Diesel Mechanic	44%	25%	13%	0%	6%	6%	13%	31%

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Suitably	Lack of Experienced
Mining Production Supervisor	47%	13%	13%	7%	7%	7%	27%	20%
SHE&Q Practitioner	53%	13%	7%	7%	7%	7%	13%	27%

Source: MQA Skills Demand and Supply Survey, 2023

Analysis of the results for the PGM mining sub-sector indicates that the mining operations manager occupation is the hardest to fill. Further analysis of the quantitative data reveals that some of the most common challenges facing employers as they relate to filling this position include a lack of experienced candidates as well as limited pools of suitably qualified candidates within the geographies that PGM mining organisations are located. Additionally, analysis of the qualitative data revealed that, within the PGM mining sub-sector, drill rig operator, electrician, diesel mechanic, and trackless machinery operator occupations are hard to fill. Employers further highlighted that the inability to fill these vacancies are due to several reasons, including the lack of a suitable blend of skills and experience, as well as an inability to match the remuneration offered by competitors.

> "Drill rig operators, electricians, diesel mechanics, auto electricians, bolter operators, and some of the trackless machinery operators. The reasons for these occupations being hard-to-fill are two-fold. For these positions, it is not the lack of supply but the lack of skills and experience. Remuneration is an issue. It is not necessarily that we are underpaying them, but the other companies have more to offer in terms of the numbers."
>
> *Employer Interview 9, 2023 (PGM)*

8.7.9 Services Incidental to Mining

The table below shows the occupations or vacancies considered to be hard to fill for employers within the services incidental to mining sub-sector. The table also provides insight into the reasons contributing to these occupations or vacancies being hard to fill.

Table 8-10: Reasons for HTFVs - Services Incidental to Mining

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Suitably Qualified	Lack of Experienced
Mining Engineer	33%	17%	0%	17%	6%	11%	17%	33%
Mining Production Supervisor	33%	11%	6%	11%	11%	6%	22%	11%
Mining Technician	37%	16%	11%	11%	5%	5%	21%	26%
Mining Operations Manager	37%	21%	16%	16%	21%	0%	16%	11%
Mechanical Engineer	39%	22%	6%	11%	6%	6%	22%	22%
SHE&Q Practitioner	41%	5%	5%	9%	18%	5%	18%	23%
Diesel Mechanic	42%	5%	5%	5%	5%	11%	21%	16%
Millwright	45%	10%	5%	0%	5%	10%	25%	10%
Driller	47%	6%	12%	0%	12%	12%	18%	6%

Occupation Roles	Not Hard to Fill	Lack of Qualifications	Lack of Access to Training	Lack of Awareness of	Lack of Funding to	Lack of Interest from	Limited Pool of Suitably Qualified	Lack of Experienced
Engineering Manager	50%	22%	0%	6%	11%	6%	17%	11%

Source: MQA Skills Demand and Supply Survey, 2023

Analysis of the results for the service incidental to mining sub-sector indicates that the mining engineer, mining production supervisor, mining technician and mining operations manager occupations are hard to fill. Further analysis of the quantitative data reveals that the most common challenges facing employers as they relate to filling these positions include a lack of experienced candidates, a lack of qualifications as well as limited pools of suitably qualified candidates within the geographies that organisations belonging to the services incidental to mining sub-sector are located.

Additionally, analysis of the qualitative data revealed that, within the services incidental to mining sub-sector, the rock drill operator ("RDO") occupation is hard to fill. Employers further highlighted that the inability to fill the RDO vacancy is due to the lack of experience of available candidates in the job market.

> "For us, it is an issue of experience. We have a lot of RDOs out there, but they lack experience. It also depends on the methods used by the mines. Some mines are mechanised [whilst] some conventional mines use handheld manual drills. If you look at our positions, it is mainly RDO's, team leaders, miners, nozzle operators, short grit helpers. Those are our key and critical positions."
>
> *Employer Interview 30, 2023 (Services incidental to mining)*

9 Findings: Skills Supply

This section presents the findings on the nature of skills supply in the MMS. This section includes an overview of learner enrolment trends, the current learning interventions available in the market, and considers the impact of changing technology on skills development interventions within the MMS.

9.1 Learner Enrolment Trends

The quantity and quality of the skills supply in the sector is determined by the provisioning of education and training through the schooling and post-school education and training ("PSET") system. Employers in the sector have contributed to the supply of skills by investing over R1.5 billion through learnerships, bursaries, skills training, internships, and adult education (Minerals Council South Africa, 2022). The figure below illustrates the number of students enrolled in MMS-related qualifications from 2017 to 2021.

Figure 9-1: Number of Students Enrolled in MMS-Related Qualifications

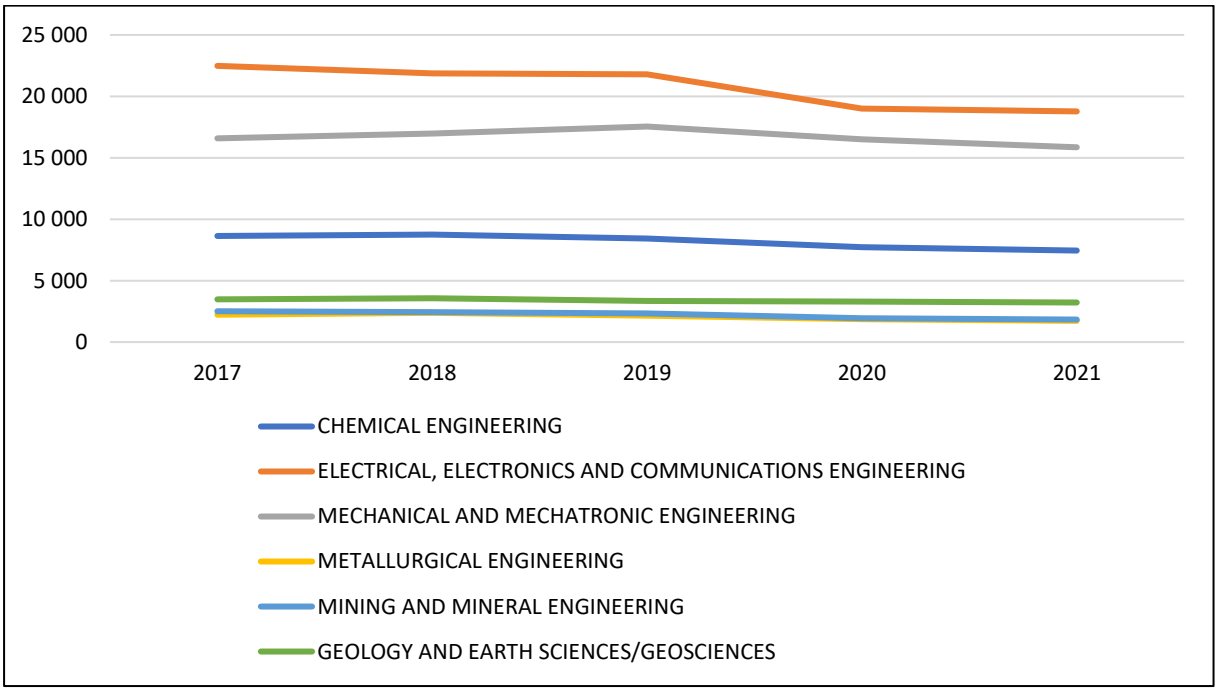


Table 9-1: Number of Students Enrolled in MMS-Related Qualifications

QUALIFICATION	2017	2018	2019	2020	2021
Chemical Engineering	8 646	8 753	8 428	7 723	7 452
Electrical, Electronics and Communications Engineering	22 483	21 876	21 786	19 016	18 778
Mechanical and Mechatronic Engineering	16 596	16 976	17 548	16 511	15 857
Metallurgical Engineering	2 243	2 383	2 140	1 856	1 730
Mining and Mineral Engineering	2 513	2 435	2 334	1 951	1 835
Geology and Earth Sciences/Geosciences	3 482	3 569	3 339	3 291	3 223

Source: DHET (2023)

In the 5-year period between 2017 and 2021, there have been a total of 266 753 enrolments across MMS-related qualifications. As can be seen in the figure above, there has been a decline in the number of enrolments for all qualifications. Electrical, electronics and communications had the highest number of enrolments while metallurgical engineering had the lowest number of enrolments.

While increasing the number of students enrolled in MMS-related qualifications is important, ensuring that these students graduate to contribute to the sector is even more critical. The figure below illustrates the number of graduates in MMS-related qualifications from 2017 to 2021.

Figure 9-2: Number of Graduates in MMS-related Qualifications

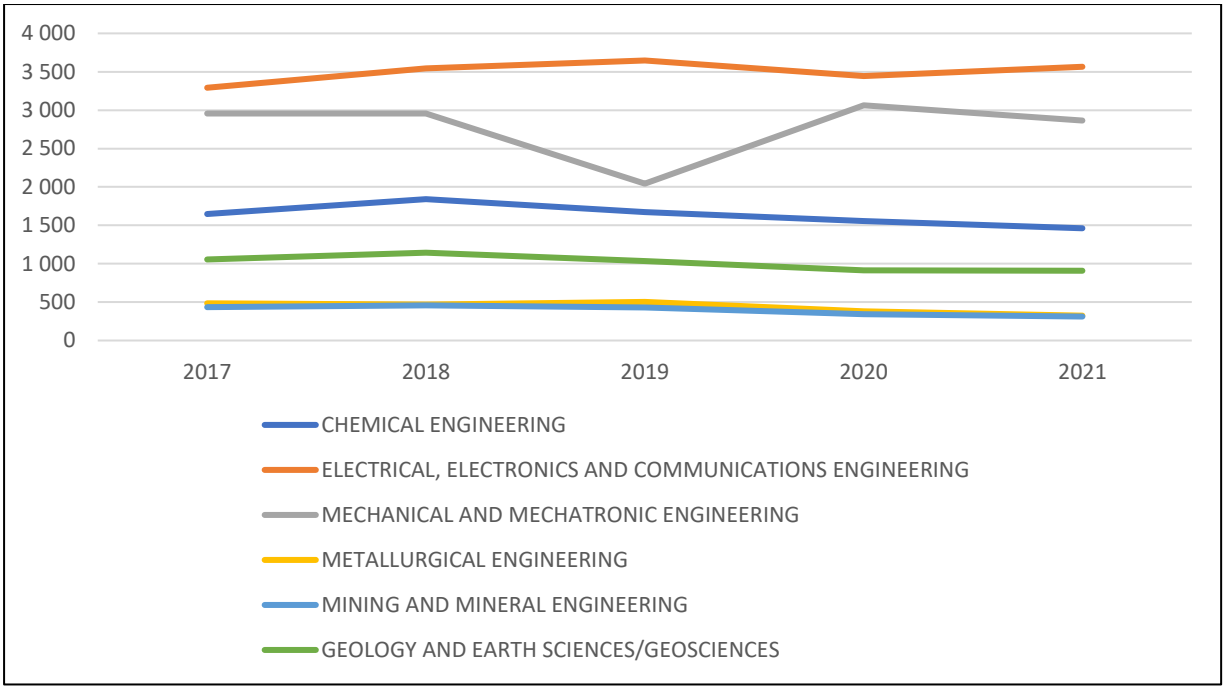


Table 9-2: Number of Graduates in MMS-related Qualifications

QUALIFICATION	2017	2018	2019	2020	2021
Chemical Engineering	1 649	1 841	1 671	1 555	1 462
Electrical, Electronics and Communications Engineering	3 292	3 546	3 647	3 446	3 566
Mechanical and Mechatronic Engineering	2 955	2 956	2 043	3 063	2 867
Metallurgical Engineering	483	469	503	380	324
Mining and Mineral Engineering	435	458	430	341	312
Geology and Earth Sciences/Geosciences	1 056	1 144	1 036	915	909

Source: DHET (2023)

In the 5-year period between 2017 and 2021, there have been a total of 48 753 graduates across MMS-related qualifications. As can be seen in the figure above, apart

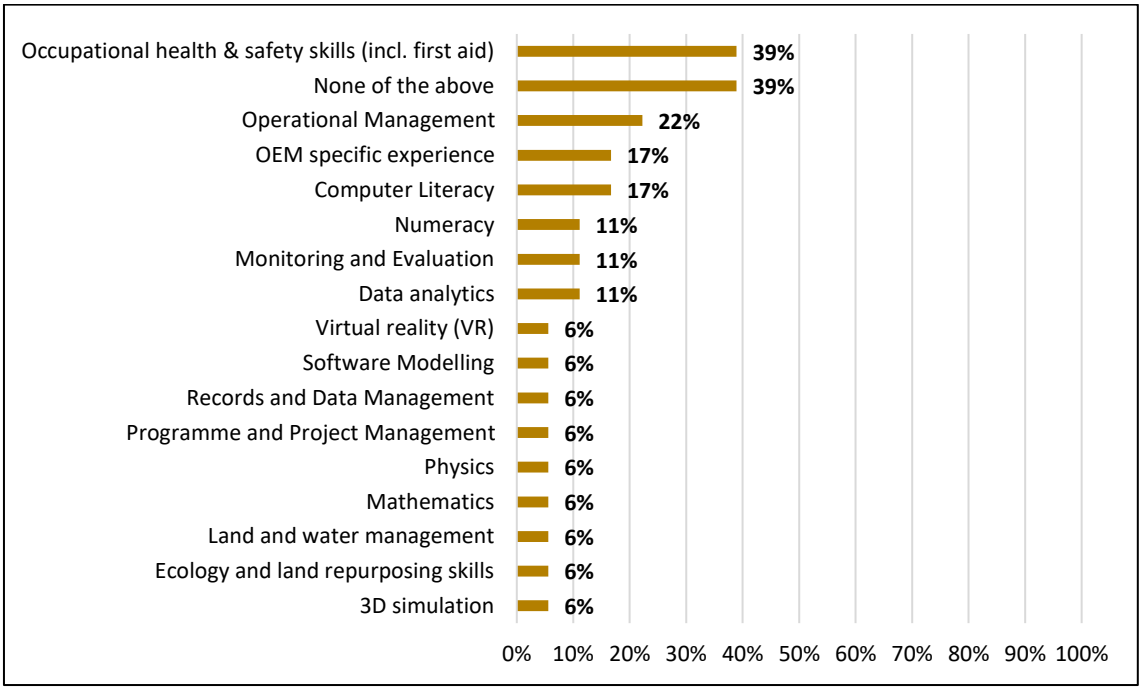
from electrical engineering, there has been a decline in the number of graduates for all qualifications between 2020 and 2021. From 2016 to 2020, the mining industry enrolled over 5,000 artisans in training and development at a cost of around R300,000 per learner and a total investment cost of more than R1.5 billion. Approximately 8,000 artisans are expected to be enrolled in artisan training and development over the next 5 years (Minerals Council South Africa, 2022).

9.2 Current Learning Interventions

The section below highlights the learning interventions that are currently available as it pertains to changing technologies and the adoption of 4IR within the MMS, as well as highlighting which of these interventions have been the most effective. It is important to understand which training interventions are perceived to be more effective as it relates to training on 4IR skills so that adequate emphasis can be placed on encouraging increased uptake of these specific types of training interventions within the MMS context.

In the current MMS skills development environment, training providers[25] within the sector offer training on a range of skills, as can be seen below.

Figure 9-3: Skills Offered by Training Providers



Source: MQA Skills Demand and Supply Survey – Training Providers, 2023

As can be seen above, 39% of training providers indicated that they offer training on occupational health and safety skills. On the other hand, 39% of training providers indicated that they do not offer training related to any of the listed skills, which suggests that a large proportion of training providers are still offering courses that align to the

[25] Training Providers, within the context of this report, refers to organisations that offer accredited skills development interventions within the MMS, and who are recognised by the MQA.

skills requirements associated with the conventional MMS context. Insight from the qualitative data suggests that this may be due to the lack of funds to purchase the relevant equipment to provide training on 4IR related skills.

> "As we move and progress in the fourth industrial revolution, a lot of things need to be done digitally but the equipment is very expensive. It is difficult for us to do it without the equipment. We have limited funds that don't allow the purchase of new and advanced equipment and doesn't allow for us to teach the students with these technologies. Grants are mainly for the operational costs which are not even enough to cover those things."
>
> *(Training Provider Interview 3, 2023)*

Further to the above, no training providers offer advanced IT and software skills, artificial intelligence, digital literacy, information systems, numerical modelling skills, planning, robotics, or technical drawing skills. These results are perhaps indicative that employers looking to upskill their employees with the abovementioned skills would have to resort to in-house training.

On the other hand, 39% of training providers have indicated that they offer occupational health and safety training, while 22% noted that they offer training related to operational management. This was closely followed by 17% of training providers who indicated that they offered OEM specific training as well as computer literacy training respectively. The provision of OEM specific training was noted in the qualitative data by certain training providers, who indicated that there are instances whereby employers will request training on specific pieces of equipment.

> "We only get requests from clients when they have [introduced] new, specialised equipment. They then ask us if we can get something aligned to that and help them to teach their employees how to operate that specific equipment."
>
> *(Training Provider Interview 17, 2023)*

In addition to being asked on what skills training is provided for, training providers were also asked to indicate what forms of training they offer, related to specific skills. These results are shown in the table below.

Table 9-3: Format of Training Provided for Specific Technologies

	Short Programm	Learnerships	Skills Programm	Work Integrated	Apprenticeship	Bursary for Diploma/De	Experientia l On-the-	My organisation does not
3D modelling	8%	0%	15 %	0%	0%	0%	0%	92%

	Short Programm	Learnerships	Skills Programm	Work Integrated	Apprenticeship	Bursary for Diploma/De	Experientia l On-the-	My organisation does not
and mapping								
3D printing	0%	0%	0%	0%	0%	0%	0%	100 %
Advanced computer use	21 %	7%	14 %	7%	0%	0%	0%	71%
AI	0%	0%	0%	0%	0%	0%	0%	100 %
AR	8%	0%	0%	0%	0%	0%	0%	92%
Automation & Robotics	0%	0%	0%	0%	0%	0%	0%	100 %
Big Data	0%	0%	0%	0%	0%	0%	8%	92%
Blockchain	0%	0%	0%	0%	0%	0%	0%	100 %
Cybersecurity	0%	0%	0%	0%	0%	0%	0%	100 %
Enhanced wearable technology	0%	0%	0%	0%	0%	0%	0%	100 %
Internet of Things	0%	0%	0%	0%	0%	0%	0%	100 %
Logistics Simulation	0%	0%	0%	0%	0%	0%	0%	100 %
Real-time information	0%	0%	8%	8%	0%	0%	0%	85%

	Short Programm	Learnership s	Skills Programm	Work Integrated	Apprentice ship	Bursary for Diploma/De	Experientia l On-the-	My organisatio n does not
managem ent systems								
Remote-controlled mining equipment	0%	0%	15 %	8%	0%	0%	0%	77%
Unmanne d Aerial Vehicles (“UAV”) technolog y (e.g., Drones)	0%	0%	0%	8%	0%	0%	0%	92%
Autonomo us Driving Vehicles/T rucks	0%	0%	7%	7%	0%	0%	0%	86%
VR	0%	0%	8%	0%	0%	0%	0%	92%

Source: MQA Skills Demand and Supply Survey – Training Providers, 2023

As can be seen in the table above, the two most common 4IR related technologies that training providers currently offer training for include advanced computer use and remote-controlled mining equipment. Furthermore, for the training providers that do provide training related to specific 4IR technologies, the most common forms of training include short programmes, skills programmes, and work integrated learning (“WIL”) programmes. It is important to note, however, that a large proportion of training providers do not provide training related to any of the listed 4IR technologies. Analysis of the qualitative data suggests that this may be due to the nature of training and skills development within the MMS, with certain training providers noting that employers prefer to conduct training related to 4IR technologies in-house, as opposed to relying on external training providers. Training providers further noted that this may be due to the generic nature of external training, with employers preferring more specialised, job-specific training.

"The mining sector itself is different to other organisations, most of the mining organisations are accredited with MQA to offer their own specialised training, hence we have the QCTO being part of developing qualifications for the occupation. When TVET colleges are involved in training people or when we send employees there it will be more theory based training as opposed to occupational based training, hence organisations typically prefer to have their own training or in house training, because its user friendly as it involves people with prior knowledge and experience with the workplace, so to send them to TVET/University is fine, but it won't fully equip them in terms of what the sector requires from them to be productive and that will meet the overall strategy of the company or the mine itself. This might be why they prefer to train their employees themselves, because of the difference between TVET qualifications and in house training. The TVET is more generic, unlike the training they get at the mine. Because the mining qualification is more specialised, e.g., in the diamond mining, there are certain processes that you do vs. when you go to PGM there is a specialised training. When we go to the core and elective qualification, they differ, so if you take someone with a TVET qualification, it may not be applicable to a specific mine, versus if you take someone who has qualified internally as a mining engineer in the diamond mine. The skills that this person has acquired at the TVET is generic."

(Training Provider Interview 6, 2023)

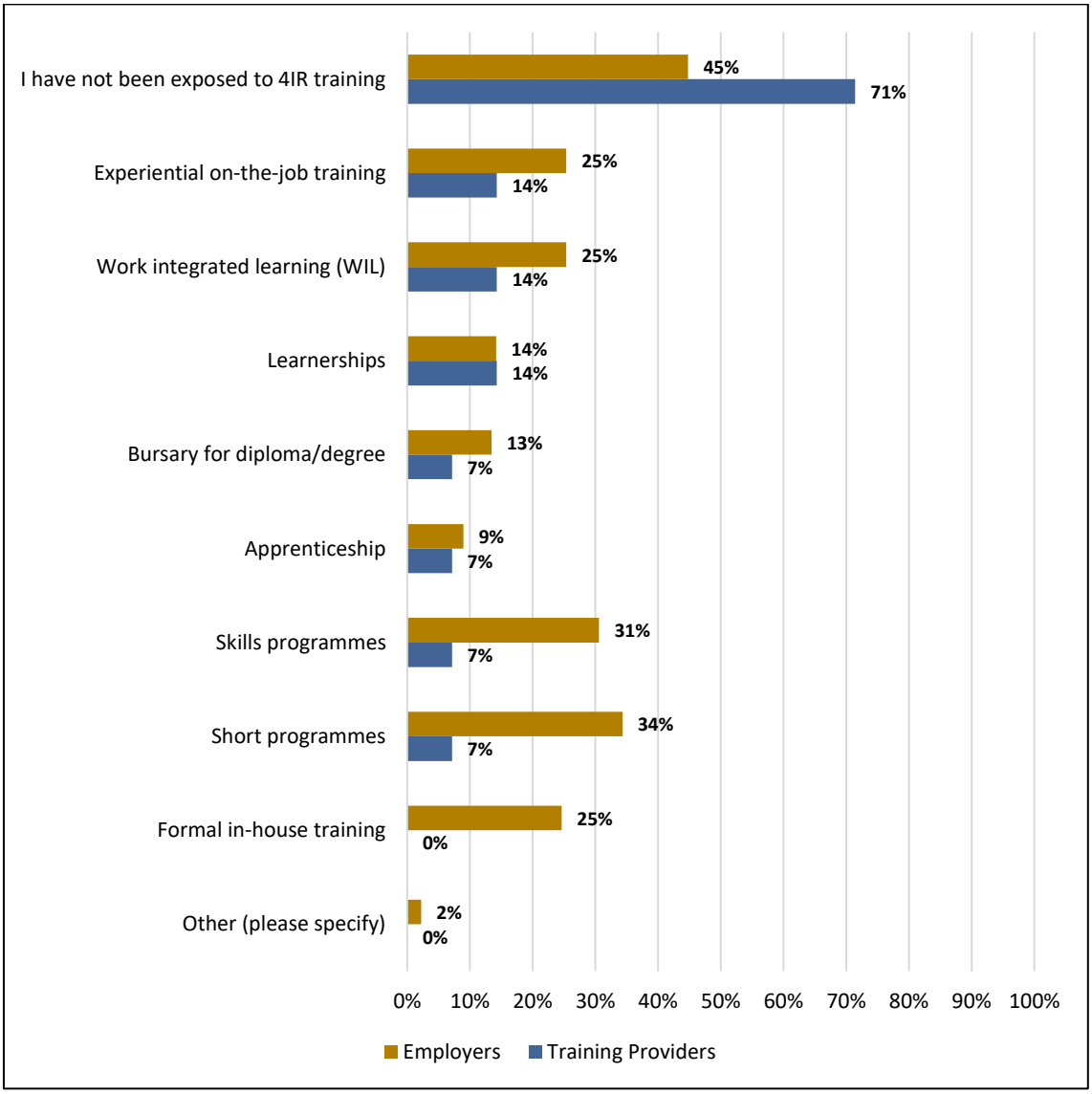
The tendency of employers to conduct internal training related to 4IR skills was corroborated by other quantitative results.

Inferential Analysis

Chi-Square tests, using a significance level of 0.05, reveal a significant relationship between the size of the employer organisation and the degree to which the organisation provides in-house training due to the availability of a training budget, with the trend being large employers more readily provide in-house training. This may indicate that large employers are better able to respond to the issue around skills gaps (that face all size organisations, as shown in section 7.2) than smaller employers.

Both employers and training providers were asked to indicate which forms of training are more effective as it pertains to 4IR skills training. The results are shown in the figure below.

Figure 9-4: Most Effective Forms of Training for 4IR Skills



Source: MQA Skills Demand and Supply Survey, 2023

As can be seen above, 25% of employers indicated that experiential, on-the-job training is the most effective form of training as it pertains to 4IR skills. Similarly, 25% of employers indicated that work integrated learning is the most effective form of training for 4IR skills. Formal in-house training was also cited as being an effective format for 4IR skills training, with 25% of employers noting this to be the case. What is perhaps most important to note from the results shown above is the large proportion of training providers (71%) who have not been exposed to 4IR training at all. This indicates that, from a skill supply perspective, there are limited 4IR related training interventions currently available in the market. This correlates with the data shown in Table 9-3, with a large proportion of training providers indicating that they do not offer training on any 4IR technologies, further underlining the lack of available 4IR skills interventions in the current skills development market.

9.3 Impact of Changing Technology on Skills Development Interventions

While it is important to understand the skills development initiatives currently available on the market, as well as the forms of training that are most effective as it pertains to 4IR skills, it is equally important to understand the impact that changing technology has on current skills development interventions available in the market.

Regarding perceptions of training providers and course curriculum, consulted employers have indicated that there is an increased need for the standardisation of course content offered by training providers.

> "There is a need to standardise [course content]. There are talks about standardising [course content] and using the same training material but that has not happened. If it were more governed or controlled, that would be better [for skills development]."
>
> *Employer Interview 17, 2023 (Diamond Mining)*

Other employers echoed these sentiments, noting that there is a need for the standardisation of specific certifications, further noting that there are varying levels of competence amongst graduates from different institutions, for both 4IR and non-4IR related skills.

> "[For both 4IR and non-4IR skills], there needs to be greater standardisation of mining certifications such as open cast blasting. Currently, there are challenges in terms of the standardisation of content across different training providers. There is a drastic difference in the quality of a learner that goes through a TVET as opposed to a university. It appears that there is no standardisation in terms of how and what learners are taught."
>
> *Employer Focus Group, 2023 (Gauteng)*

Stakeholders also indicated that more emphasis needs to be placed on proactively reviewing the current curriculum to ensure that adequate focus is placed on future skills requirements.

> "The curriculum at large needs to be looked into, [more] focus [needs to be placed] on what will be done in the future. MQA needs to facilitate the process of revising the curriculum to make sure that it is relevant for the industry and [to ensure] the adoption of a forward-thinking approach to skills development."
>
> *Training Provider Interview 11, 2023*

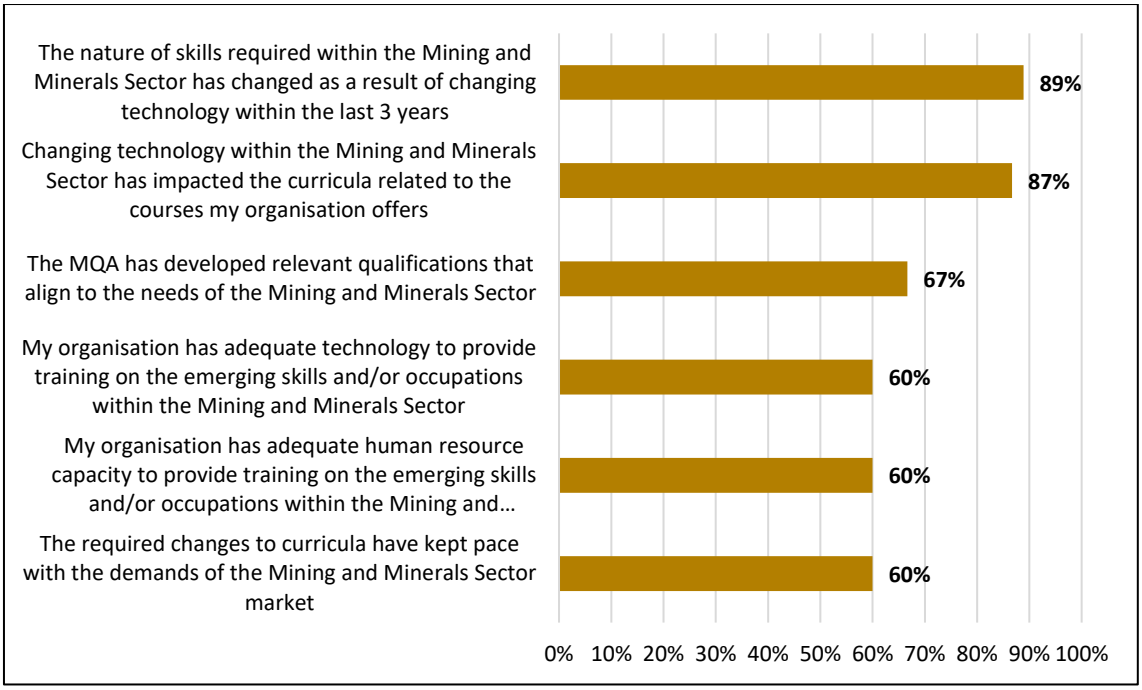
This view aligned with insights emerging from other qualitative consultations, with certain employers highlighting the need for learning material to reflect the current MMS context, indicating that current learning material is more aligned to conventional mining as opposed to mechanised mining operations. Employers also cited the need for a standardised and generic 'training Bible', which, in their view, needs to clearly indicate the specific training methodology that training providers would need to follow in the provisioning of training for a specific skill.

> "As we know, the mining industry has been using conventional mining methods. So, with the new trend of moving towards mechanisation, all MQA learning material is based on conventional mining methods, so there is a definite shortfall. [Learning material] is more applicable to what skills are required in the conventional [context], and the adaptability towards mechanisation has not been addressed yet. What makes it a little bit difficult with the different mining houses is not all of them are using the same equipment, so it is different OEMs providing different machines. So, what needs to happen is we need to establish a generic *'training Bible'* towards what is a roof bolter. You need to have a basic training methodology surrounding all the different equipment that is currently used in the mechanised world. You cannot go to specific machines because the application of the machines differs, the control system differs, the methodology and the activity of the machine differs. So, if you can say it's a drill rig but in the world of mining there's about 13 different applications of a drill rig. But for that application - that requirement you're going to need, you're going to need to have a generic kind of a training methodology established to say that if he has done drilling, it means he can understand what a drill rig is about. But it's not about the specific machine and application.
>
> *Employer Interview 5, 2023 (PGM)*

Furthermore, consulted employers share the view that course curricula have, for the most part, remained the same despite 4IR related developments within the sector. It was also noted that training providers need to enhance their offerings and ensure that course content is cognisant of changing technologies to ensure that learners are aware of and are able to operate more sophisticated technical machinery once they are implemented in the sector.

From the perspective of training providers, only 60% believe that the required changes to curricula have kept pace with the demands of the MMS market. When considering that 87% of training providers indicated that changing technology within the MMS has impacted their course curricula, it becomes evident that there is room for improvement in terms of course content keeping abreast with the latest developments within the sector.

Figure 9-5: Impact of Changing Technology on Training Providers



Source: MQA Skills Demand and Supply Survey – Training Providers, 2023

When asked to specify the ways in which changing technology has impacted course curricula, certain training providers indicated that specific courses have been adapted due to changes in the manner in which certain pieces of equipment are operated in the current MMS context.

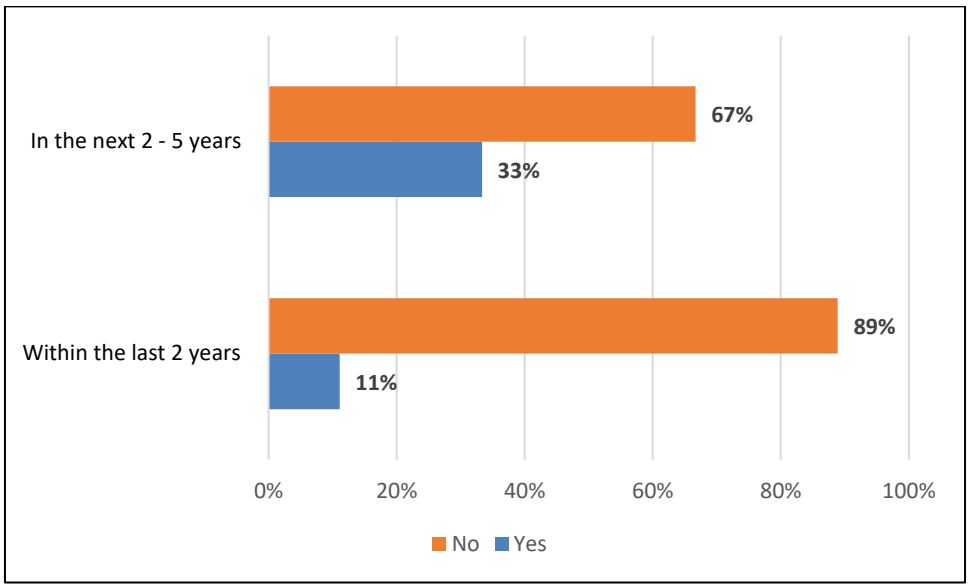
> "Drills are now completely automatic – there is no more manual operation. It is a completely different environment and [requires] completely different training."
>
> *(Training Provider Survey, 2023)*

Other training providers shared similar sentiments, noting that the job descriptions of specific mining related roles have changed, which necessitates changes in course content as it pertains to the training provided for said roles.

> "Operators no longer perform the functions they used to 20 years ago. Content needs to change, [current] operator standards [are] not indicative of what the job role [is]."
>
> *(Training Provider Survey, 2023)*

While it is evident that there is a need to update course content to be more relevant to the current MMS context, which is supported by the fact that 87% of training providers have indicated that changing technology has impacted on their course curricula - only 11% of training providers have noted that the qualifications that their organisation currently offers have become redundant in the past 2 years, as can be seen below.

Figure 9-6: Redundant Qualifications[26]



Source: MQA Skills Demand and Supply Survey – Training Providers, 2023

The results shown above are interesting to note because it suggests that while changing technology has had an impact on course curricula, the qualifications and/or courses on offer are still perceived to be relevant in the current context. However, as seen in the figure above, 67% of training providers have indicated that they expect their qualifications to become redundant in the next 2 – 5 years. This indicates that while qualifications are perceived to be relevant in the current context, the landscape as it pertains to skills development needs will change in the next 2 years, which necessitates the need to update course curricula and learning content.

In addition to concerns around the relevance of course content, challenges relating to the capacity of training providers within the MMS as it relates to the provision of 4IR related training were also noted in the quantitative and qualitative data. As can be seen, only 60% of training providers indicated that their organisation has the adequate human resource capacity to provide training on emerging skills and/or occupations within the MMS. This was corroborated by insights from the qualitative data, with several training providers citing the lack of qualified facilitators and assessors as being a key challenge limiting their ability to provide training on emerging skills within the MMS, further noting that trainer upskilling is required. Several training providers also cited MMS specific facilitators and assessors as being key occupational shortages within the MMS.

Another key challenge identified through qualitative analysis relates to access to sufficient technology, with several training providers noting access to resources and funding as being a challenge impacting on their ability to provide training on emerging skills and technologies. This was somewhat supported by the quantitative findings, with

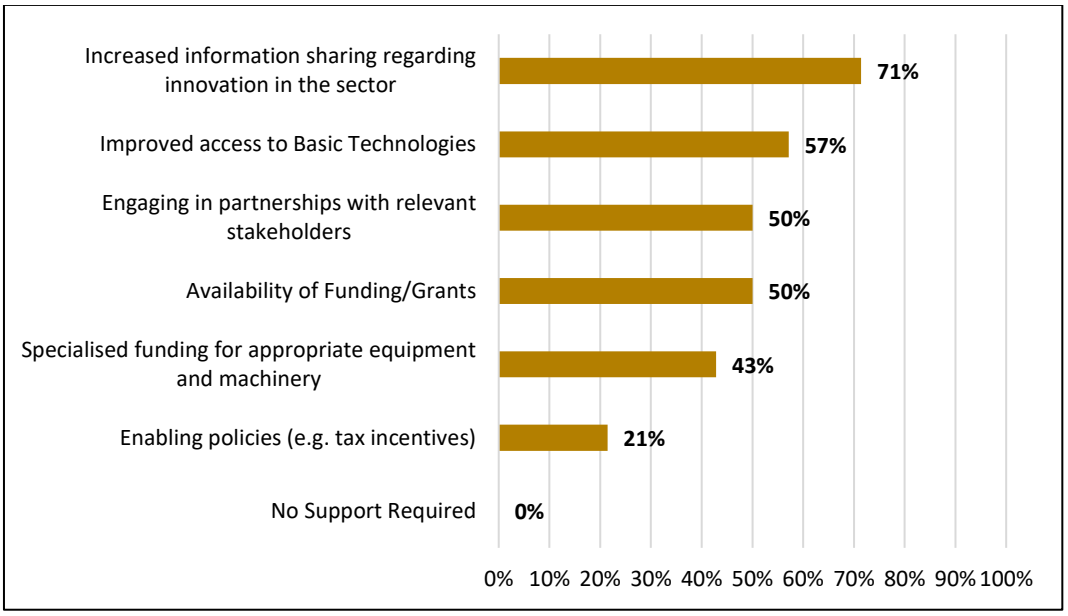
[26] Training providers were asked: "have any qualifications offered by your institution become redundant as a result of the implementation of new technology within the last 2 years?" A similar question was posed to gather training provider views regarding redundant qualifications in the next 2 to 5 years.

only 60% of training providers indicating that their organisation has adequate technology to provide training on the emerging skills and/or occupations within the MMS.

> "Currently training is done manually, and it is not where the world is going, so we must move from doing things manually and go digital. [However], without the necessary funds to access these types of technologies, there is no way we can go digital. The basics of the courses will stay the same [but] the equipment needs to be bought from international suppliers - you cannot get it locally. The international taxes and the levies then make the equipment even more expensive.
>
> *(Training Provider Interview 3, 2023)*

While it is important to understand the challenges impacting on training providers' ability to conduct training on emerging skills within the MMS, it is equally important to consider what forms of support said training providers require to play a more critical role as it pertains to skills development for emerging skills within the sector. As such, the figure below provides insight on the forms of support required to provide training on emerging skills within the sector, as reported by training providers.

Figure 9-7: Support Required by Training Providers



Source: MQA Skills Demand and Supply Survey – Training Providers, 2023

As can be seen, 71% of training providers indicated that increased information sharing regarding innovation in the sector is required. Qualitative input suggests that increased information sharing may assist training providers in terms of ensuring that their offerings are aligned with the latest developments and trends in the sector.

> "[We need] access to information on how the industry is changing. [We need there to be] deliberate focus on what [training providers] need to do to train differently."
>
> *(Training Provider Survey, 2023)*

Other stakeholders echoed these sentiments, noting that information sharing is key to ensuring that training providers are aware of the forthcoming changes within the MMS.

> "Definitely, [I would say that] partnerships and information sharing between public and private [sectors] are very important. No government institution can work in a silo. Every policy that gets propagated needs to be thoroughly researched and shared with business, so that business also gears up to what changes are going to be enforced within the next 3-5 years or even 10 years."
>
> *(Training Provider Interview 5, 2023)*

Access to technology was also cited as being a key form of support required, with 57% of training providers indicating that they require improved access to basic technologies. The result relating to improved access to basic technologies is important to note, particularly since one of the key findings emerging from the qualitative data relates to the positive impact that 4IR may have on education and training within the sector. Several employers have noted an increased uptake of e-learning initiatives, as well as the use of VR and AR as part of simulated training interventions.

> "So, in the [training] space, we are looking at implementing VR. We have got 360° VR that we want to use in training and then we are [also] going to have surface mock-ups where we will have real machines where employees can practise before they get exposed to the real practical production world where they need to go and do their job."
>
> *Employer Interview 5, 2023 (PGM)*

These sentiments were echoed in other interviews, with certain employer representatives noting the increased uptake of simulated training interventions, while also highlighting the positive safety implications associated with simulated training interventions.

> "[We are] looking to do barring training with virtual reality without exposing the people to the real danger. [Barring] involves removing loose rocks from hanging walls – it is dangerous work because there is always a possibility of a rock that can dislodge from the hanging wall and injure people severely. So, that is why we want to use simulators so that we can do this training with virtual reality units without exposing them to the real danger."
>
> *Training Provider Interview 12, 2023*

However, it is important to note that the increased uptake of e-learning appears to be more prevalent within the context of internal, organisational training as opposed to external training. External training providers in the sector have generally continued to use traditional methods in the provisioning of skills development in the sector with a few citing the use of 4IR technologies such as simulators that make use of virtual reality to train supervisory level employees on mining functions, the mining cycle and how to optimise human as well on ventilation training and blasting sequence training.

> "Yes, we do [use technology]. We have 3 different simulators that are being used for training on the trackless mobile machines, simulators for personnel carriers are being used as well. These simulators make use of virtual reality - it covers the whole mining cycle. This simulator is used for training supervisory level employers and trains them in terms of mining functions, the mining cycle, as well as ventilation and blasting sequence training. This type of training is now being done with simulators."
>
> *Training Provider Interview 12, 2023*

Another insight from the qualitative data relates to the challenges associated with e-learning initiatives. Several training providers indicated that while they understand the benefits that may come with e-learning, there are several limitations of providing training through virtual mediums. For example, certain train providers noted that mining organisations typically employ members of the communities in which they operate who are not able to make use of such platforms due to a lack of digital as well as basic numeracy and literacy skills. This sentiment aligns with those emerging from employer consultations, with employers indicating that a lack of basic digital literacy skills poses challenges regarding the upskilling of employees internally.

> "We need to train our employees with basic computer skills because there are employees that are not even familiar with a computer. When we try to move to other training that is through digital mediums, they fall behind. With the basic training on computers, it will be easy to introduce them to other, more advanced courses. The lack of basic digital literacy is a problem."
>
> *Employer Interview 28, 2023 (Services Incidental to mining)*

Touching on a similar theme, other employers noted that the lack of digital literacy skills poses a challenge to effective training. It was further noted that beyond a lack of digital literacy, the lack of basic numeracy and literacy exacerbates training challenges.

> "We have a combination of [different ages] within our workforce: the older generation closer to retirement and [the] younger generation who is more flexible with regards to new technology. There is still a challenge with the older employees, we see that when we go to computer-based training. English literacy is lacking, science and maths skills are lacking as well. So, there are low levels of education involved there."
>
> *Training Provider Interview 4, 2023*

Regarding other forms of support required from training providers, 50% of respondents indicated that engaging in partnerships with relevant stakeholders would allow them to provide training on the emerging skills within the MMS. This aligned with sentiments emerging from the qualitative data, with certain stakeholders noting that forming partnerships are key in terms of ensuring that there is greater alignment between MMS market requirements and learning interventions.

> "There needs to be more partnerships between training providers and businesses within specific geographies to ensure greater alignment from the perspective of skills development."
>
> *Employer Focus Group, 2023 (Gauteng)*

10 Positive Practices and Areas for Improvement

Regarding positive practices and areas for improvement for the MQA to consider, the majority of stakeholders indicated that the MQA has done well in engaging stakeholders in the sector through various meetings and workshops.

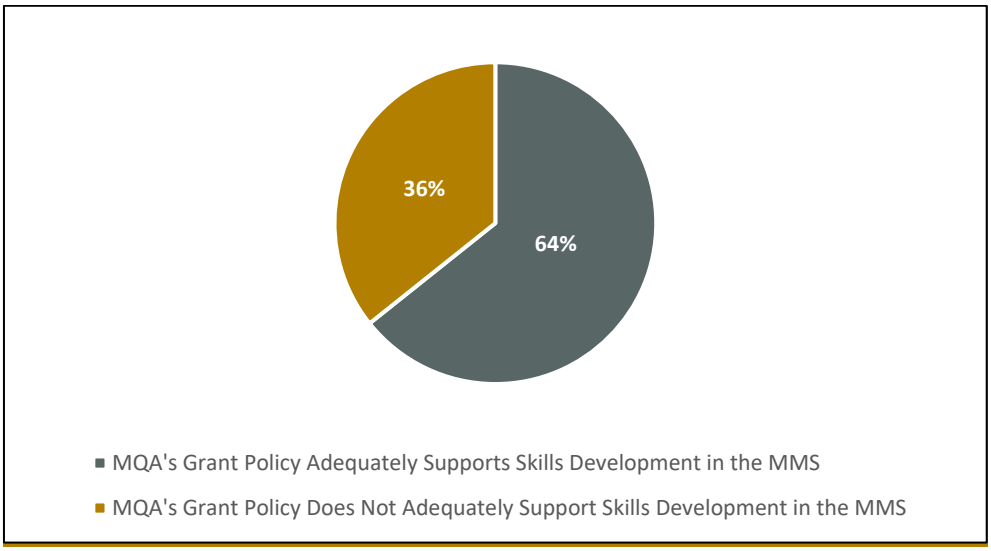
> "I think in terms of communication, this is what they are doing well. They also help companies collaborate and transfer skills. They are always involved in different research, as well as stakeholder engagements with different mining houses."
>
> *Employer Interview 30, 2023 (Services Incidental to mining)*

Furthermore, several stakeholders lauded the MQA for consistently gathering feedback from its stakeholders and adapting its strategies to ensure that it effectively addresses the skills development needs of organisations in the mining sector. Stakeholders also highlighted communication as being a positive practice, indicating that the MQA continually engages and communicates with its stakeholders.

> "There has been a huge improvement with stakeholder engagement. Since last year, they are giving us more opportunities to share feedback. Very important that they consult with different organizations or different SETAs as well, or different minds; different stakeholders are needed in terms of the skills need so that they can identify those skills shortages in the different areas."
>
> *Employer Interview 32, 2023 (PGM)*

In addition to the above, analysis of the quantitative data reveals that training providers appeared to be satisfied with the MQA's grant policy, with 64% of training providers indicating that the MQA's grant policy adequately supports skills development within the MMS, as can be seen below.

Figure 10-1: Perception of MQA's Grant Policy



Source: MQA Skills Demand and Supply Survey – Training Providers, 2023

Furthermore, when asked to provide qualitative input on what the MQA does well regarding addressing the skills development needs of the broader MMS, training

providers indicated that the MQA does well regarding their product offerings, lauding the wide range of qualifications and skills programmes available through the MQA. Other training providers expressed their satisfaction with the frequency and informative nature of workshops conducted by the MQA, lauding the MQA's commitment to informing stakeholders regarding the ways in which training providers can adapt and develop their learning material.

> "I am very happy; they are informative and are always conducting workshops. They invite us as stakeholders for specific qualifications to have group meetings on how we can align and how we can develop learning material. MQA is doing very good to involve the stakeholders."
>
> *(Training Provider Interview 14, 2023)*

Regarding areas for improvement, consulted stakeholders have indicated that the MQA should look to increase the types of skills and qualifications they support, with some stakeholders suggesting that the MQA assists employers with MOUs with other SETAs for qualifications that the MQA does not support.

> "We work with a university in the study of soil because its relevant to what we are doing, but the MQA will not support that; personally, in the past we have sponsored someone's Masters in soil studies. Maybe we need a memorandum of understanding with another SETA, in a different realm to what MQA is currently offering.
>
> *Employer Interview 23, 2023 (Other Mining)*

> "What I do think the MQA can look at is the sponsorship of the skills, now they have a suite of skills - I call it a suite that they say they do sponsor; maybe that can be enhanced and extended. It is very narrowed, and we do not only work with those skills, the skills and the businesses that we do work with is a little bit broader than that. If you look at a typical contractor that is within manufacturing but has received a contract within mining, it will want to have some skills, but it is more to the manufacturing, but that does not fall within the suite of grants that the MQA offers, maybe a different way of enhancing that.
>
> *Employer Interview 23, 2023 (Other Mining)*

Another area for improvement includes increased communication from the MQA around the available, relevant, and accredited training initiatives that can drive technology adoption within the sector, as well as increased communication and workshops relating to the different types of 4IR technologies available in the market. Certain employers also indicated that the MQA should consider providing specific funding for 4IR specific training interventions.

As it pertains to improved communications, certain training providers noted that there is a need for a central information hub or communication platform, which would allow the MQA to communicate critical information to training providers within the MMS.

> "There should be one platform that makes it possible for the MQA and training providers to be on the same page. So, if there are changes being conveyed to MQA, they can convey them securely to the providers. Because we as training providers work hand in hand with the MQA. But when it comes to certain things, we don't even know them. So that would be the biggest change. If this can be one place where we can communicate and it's clear and up to date, that will be awesome. A portal, or LinkedIn, used for communication. As a training provider, if there are any changes made to legislation or regulations, it affects us end user mostly. They should be clear on changes on certain things as we need to work with them most up to date information."
>
> *(Training Provider Interview 17, 2023)*

Turnaround time as it pertains to applications was also cited as being an area for improvement, with certain employers noting that their organisation cannot afford to wait for the MQA to approve their application before hiring students, which results in discrepancies between the number of students hired and the amount of funding received from the MQA.

> "With MQA, I am happy with the grants and everything else. However, when it comes to the turnaround time, I think they do take time to respond. I know there are internal processes when we apply for the grants and so on, but the turnaround times are long. If we apply now and we want to recruit in the next year, it takes too long. Like they say in their policy, before you offer employment to students or interns you should make sure that you have got a client letter from MQA. So, sometimes they are very late and as a company we need to move on. We cannot wait for MQA. So, sometimes we find that we have employed more students than what they are giving us, and we have to live with that. But if they can improve when coming to turnaround time, I think that will be better.
>
> *Employer Interview 28, 2023 (Services Incidental to mining)*

This was echoed in other qualitative consultations, with several employers noting that despite the MQA performing well in terms of the provision of funding for skills development, there is room for improvement as it pertains to turnaround times for applications.

> "MQA does well in terms of providing funds to the sector for training. I do not think there is much to improve - maybe turnaround times for applications."
>
> *Employer Interview 24, 2023 (Services Incidental to mining)*

In addition to the above, certain employers also noted the need for the MQA to assess the capacity and capability of subject matter experts and/or training providers. Employers noted that certain training providers 'cut corners' when providing training and indicated that there is a need for the MQA to improve its monitoring processes during site visits.

> "MQA really needs to look into the capacity and capability of the subject matter experts that they are using. I've seen many providers that are cutting corners because they need to make more money. So MQA needs to tighten up in terms of getting the necessary expertise when they do the site visits. Other than that, besides the grants then they are doing what they can."
>
> *Training Provider Interview 11, 2023*

11 Key Findings

The table below provides an overview of the key findings emerging from the Project.

Table 11-1: Key Findings

#	Focus Area	Finding
1	HTFVs	• At an overall level, mining operations manager, engineering manager, mechanical engineer, and mining engineer occupations were identified as hard to fill by employers within the MMS. The sub-sector view is largely reflective of this, with the only significant exceptions being the diamond mining sub-sector, which noted SHE&Q practitioner, diamond cutter, and diamond polisher occupations as hard to fill in addition to engineering related roles. • It was found that, for recently qualified engineers, the MMS is not considered to be an attractive destination. This is partly due to a lack of competitive salaries offered by organisations within the MMS, as well as the geographical location of organisations within the MMS, with graduates preferring to work in more urban areas. • The most common reasons underpinning employers' challenges as it relates to filling HTFVs include a lack of qualified candidates, a lack of experienced candidates, as well as challenges related to geography, whereby organisations have limited supplies of suitability qualified candidates within the area that said organisations are based.
2	Impact of Changing Technology on the MMS	• While there are several organisations who have implemented more sophisticated technologies within their organisations, a large proportion of employers have not fully embraced 4IR as it pertains to fully mechanising their operations. • Financial constraints appear to be limiting the uptake of more sophisticated technologies, with several employers noting that the lack of funding impedes on their ability to adopt said technologies fully. • Financial constraints appear to be a challenge for smaller sized organisations, with several employers noting that the cost of implementing new technologies outweighs the benefits. Stakeholders from small organisations also cited the cost of upskilling their employees as being a challenge which impacted their ability to provide training on 4IR skills.

#	Focus Area	Finding
		• While certain employers noted the benefits associated with the introduction of more sophisticated technologies from an organisational perspective (particularly in terms of increased efficiency and productivity), the general sentiment emerging from the data is that employers need to integrate new technologies in a manner that balances employee interests with organisational benefits.
3	Skills Gaps	• Overall, key skills gaps in the MMS include management, leadership, digital literacy, and technical (i.e., job specific) skills. Employers also cited advanced IT and software skills as being in short supply. • While leadership skills gaps appear to be prevalent across all sub-sectors, the results indicate that leadership skills are a specific concern within the diamond mining, other mining, and services incidental to mining sub-sectors. Management skills gaps are also common across all sub-sectors, apart from the diamond processing sub-sector. Technical skills gaps were also noted across all sub-sectors, apart from diamond mining. • As it pertains to digital literacy skills gaps, the findings indicate that all sub-sectors recognise digital literacy as being a major skills gap, apart from the coal mining and CLAS sub-sectors. Similarly, skills related to predictive analytics have been noted as being in short supply across all sub-sectors. • Regarding skills gaps specific to certain sub-sectors, numerical modelling skills have been identified as a skills gap within the diamond processing and PGM mining sub-sectors.
4	Impact of Changing Technology on Occupations and Skills	• Overall, it was found that a large proportion of organisations need to reskill and/or upskill their employees should they have plans to introduce new technologies within their organisation. Of the employers that responded to the survey, 86% indicated that their employees require upskilling and/or reskilling to operate new technology that has been introduced within their organisation's operations. • Specific occupations must evolve and will require skills that will enable employees to make use of changing technologies. For example, machine operators will need to become more technically skilled to ensure that they are able to assist with the maintenance of the machines that they are operating. Further to the above, it was found that machine operators will

#	Focus Area	Finding
		require basic digital and fault-finding skills to make use of more sophisticated technologies. • It was found that one of the key challenges impacting on employers' ability to upskill their employees is the lack of basic digital skills amongst employees. In addition to a lack of basic digital skills, there appears to be a lack of basic numeracy and literacy skills amongst MMS employees which needs to be addressed before companies consider upskilling related to 4IR skills.
5	Skills and Occupations in Demand	• The key soft skills that will be in demand in the next 1-2 years include judgement and decision making, change management, innovative thinking, problem solving, and leadership skills. Skills related to adaptability will also increase in demand in the short-term future. • The key technical skills that will be in demand in the next 1-2 years include computer literacy, data analytics and digital literacy skills. Project management, planning and data analytic skills were also noted as being skills for which demand will increase in the short-term future. • Regarding occupations in demand, analysis of the results reveal that data analysts, information systems specialists, application developers, and electrical engineers are perceived to be the occupations for which demand will increase in the short-term future.
6	Awareness around 4IR and Changing Technology	• Several employers and training providers believe that the implementation of more sophisticated technology is being hindered by a lack of awareness around the benefits of changing technology, as well as a lack of awareness as it pertains to the impact of changing technologies on employment. • It was found that employers do not fully comprehend what the implications of 4IR are going to be in the long term, with several employers' citing the need for research and analysis to be conducted on whether the benefit of implementing new technology outweighs the associated costs. Several employers were of the view that it would be cheaper for their organisation to continue conducting their operations as they have been doing, instead of transitioning to mechanised operations.

#	Focus Area	Finding
		• It was found that there is reluctance amongst employees as it pertains to the uptake of 4IR technologies. This is primarily due to the negative stigma associated with new technologies, with it being seen as a catalyst for large scale retrenchments.
7	Impact of Changing Technology on Skills Development Interventions	• It was found that the learning material currently available on the MMS market has remained the same and has not been updated to be cognisant of the changing technologies used by organisations in the sector. The current learning material available on the market is largely aligned to conventional mining methods (for example, several employers noted that while their organisation makes use of automated dozers, 'Trackless Mobile Machine Operations' skills programmes accessible through the MQA only provides training on the use of traditional track dozers and wheel dozers). There is therefore an urgent need to update learning material to align with the current changes occurring within the sector as it pertains to changing technology. In addition to updating learning material, several employers noted that there is a need to standardise learning material offered by external training providers, given that there appears to be varying levels of competence amongst graduates from different institutions. • Regarding the support required by training providers, 71% indicated that increased information sharing as it pertains to innovation in the sector would help training providers to ensure that their offerings are aligned with the latest developments and trends in the MMS. Access to technology was also cited as being a key form of support required. • External training providers have generally continued to use traditional methods to provide training to employees within the MMS. However, there has been increased uptake of e-learning initiatives amongst employers for the purposes of

#	Focus Area	Finding
		internal training. While both employers and training providers have noted that e-learning has numerous benefits (particularly improved safety), several stakeholders noted challenges as it pertains to e-learning within the MMS context. These challenges include a lack of basic numeracy and literacy skills, as well as a lack of digital literacy amongst MMS employees.
8	Current Skills Development Interventions Available on the MMS Market	• A large proportion of training providers offer skills development interventions that align to the conventional MMS context. It was found that this is primarily due to the lack of funding to purchase the required equipment to provide training on emerging skills, as well as a lack of suitably qualified assessors and/or moderators. • The two most common 4IR technologies that training providers offer training for include advanced computer use and remote-controlled mining equipment. As it pertains to format, the most common forms of training include short programmes, skills programmes, and work integrated learning programmes. • Regarding interventions considered to be effective as it pertains to 4IR training, it was found that experiential, on-the-job training, and formal in-house training are the most effective formats. • There appears to be a lack of 4IR training interventions available to employers on the external market. This is evidenced by the large proportion of training providers who indicated that they do not offer training related to 4IR technologies as well as the 71% of training providers who indicated that they have not been exposed to 4IR training.

#	Focus Area	Finding
		• As a result of the lack of available 4IR training interventions within the external market, the demand for OEM training (i.e., training provided by OEMs) has increased. This increased demand has meant that many employers must wait for extended periods of time in order to ensure that their employees are equipped with the relevant skills to operate new machinery.
9	Positive Practices	• The majority of stakeholders indicated that the MQA has done well in engaging stakeholders in the sector through various meetings and workshops. Furthermore, several stakeholders lauded the MQA for consistently gathering feedback from its stakeholders and adapting its strategies to ensure that it effectively addresses the skills development needs of organisations in the mining sector. Stakeholders also highlighted communication as being a positive practice, indicating that the MQA continually engages and communicates with its stakeholders.

#	Focus Area	Finding
10	Areas for Improvement	• Regarding areas for improvement, consulted stakeholders have indicated that the MQA should look to increase the types of skills and qualifications they support. • Other areas for improvement include increased communication from the MQA around the available, relevant, and accredited training initiatives that can drive technology adoption within the sector, as well as increased communication and workshops relating to the different types of 4IR technologies available in the market. • Training providers indicated that there is a need for a central communication platform which would allow the MQA to disseminate relevant information that impacts on training providers in a swift manner. • Several employers indicated that the MQA should adopt stricter monitoring processes when conducting training provider site visits, to ensure that training providers are providing training that is of the required standard.

12 SMART Recommendations

The below provides a set of implementable recommendations, drafted in terms of the SMART criteria. We note that the degree of implementation of each recommendation will be dependent on the MQA's available budget and should be considered within this context.

12.1 Recommendation 1: Increase MMS Sector Attractiveness at School Level

To address the issue of a lack of qualified candidates, the MQA should implement targeted career awareness campaigns in schools and universities to inform students about the opportunities and benefits of pursuing careers in the mining sector.

Activity:	Conduct MMS career awareness sessions at high schools, targeting Grade 10 to 12 students. These sessions to focus on explaining the different career paths available to employees, earning potential and required tertiary education
Frequency/Timeframe:	Twice annually, to target as many schools as budget will allow.

To supplement the above, the MQA may consider distributing information packs, to schools, with the above indicated relevant content so that schools can further distribute this information to students.

12.2 Recommendation 2: Develop Talent Attraction Strategies Based on Best Practices

To address the limited supply of suitably qualified candidates within specific geographies, the MQA should commission a research study aimed at establishing best practices on attracting suitably qualified and experienced talent to the MMS. The findings of this research should be disseminated to MMS employers.

Activity:	Conduct research on best practices related to the development of a talent attraction strategy within the MMS sector. This research should provide clear insight on practices and interventions regarding the most effective manner that organisations within the MMS can utilise in order to attract and retain employees.
Frequency/Timeframe:	Research to be conducted within the next year; information from research to be shared in information sharing sessions and workshops, which should occur quarterly.

12.3 Recommendation 3: Develop Clear Career Development Pathways for MMS Employees

To enhance the professional growth and retention of skilled talent within the MMS, the MQA, in collaboration with employers, should establish transparent career development pathways for MMS employees. By fostering a supportive environment for professional development, the MQA can incentivize talented individuals to commit to long-term careers within the MMS, ultimately contributing to its sustained growth and success.

Activity:	Develop clear career development pathways in collaboration with specific employers within specific MMS sub-sectors. Collaboration with employers should occur through outreach and engagement initiatives such as sub-sector specific workshops, webinars, or seminars. These pathways, which should be documented in the form of an information pack, should incorporate clear opportunities for career advancement and specialisation, providing a roadmap for individuals to navigate their professional journey within the MMS.
Frequency/Timeframe:	Career development pathway information pack to be developed within the next year, information contained within the career development pathways information pack to be communicated to MMS stakeholders on a quarterly basis, and to be updated annually, to account for MMS sector developments such as emerging occupations.

12.4 Recommendation 4: Continued Focus on Developing Basic Numeracy and Literacy Skills

To address the lack of basic numeracy and literacy skills amongst MMS employees, it is recommended that the MQA continues to prioritise the provisioning of funding for Foundational Learning Competence Programmes and Adult Education and Training Programmes. While it is noted that the MQA has made significant progress in improving the level of basic numeracy and literacy skills through its Foundational Learning Competence and Adult Education and Training programmes and is attempting to focus more on providing funding for digital elementary skills, the findings indicate that the lack of basic numeracy skills is still a concern for employers attempting to train their employees. Basic literacy and numeracy skills are foundational and should be seen as critical ‘building blocks’ which will allow employees to engage in more advanced training related to 4IR skills.

Activity:	Continue prioritising the provisioning of funding for Foundational Learning Competence Programmes and Adult Education and Training Programmes focused on developing basic literacy and numeracy skills.
Frequency/Timeframe:	Activity to be conducted annually, in line with MQA’s discretionary grant planning processes.

In addition to the above, given that employees belonging to specific occupational groups (e.g., such as plant and machine operators and assemblers) appear to be at risk of being impacted by the implementation of 4IR technologies, the MQA should consider revising discretionary grant funding guidelines for AET and FLC programmes to prioritise the enrolment of individuals belonging to the abovementioned occupational groups into said programmes. This may serve to equip these individuals with basic numeracy and literacy skills which may allow them to participate in more advanced training associated with digital, computer, and 4IR related skills.

Activity:	Revise funding guidelines for AET and FLC programmes to prioritise the enrolment of individuals belonging to specific occupational groups (such as elementary workers and plant and machine operators and assemblers) into said programmes.
Frequency/Timeframe:	Activity to be conducted annually, in line with MQA's discretionary grant planning processes.

12.5 Recommendation 5: Continued Provisioning of Funding for ARPL Programmes

Given that a large portion of MMS employees do not have qualifications, the MQA should continue the provisioning of funding for ARPL Programmes, in order to ensure that MMS employees are able to attain their trade qualifications.

Activity:	Continue prioritising the provisioning of funding for ARPL Programmes focused on assisting employees to attain their trade qualifications, which will ultimately result in more qualified and capacitated MMS workforce.
Frequency/Timeframe+:	Activity to be conducted annually, in line with MQA's discretionary grant planning processes.

12.6 Recommendation 6: Increase the Development of Soft Skills within the MMS

To address soft skills gaps, as well as to meet the demand as it pertains to the soft skills for which demand will increase within 1 to 2 years, the MQA should consider reviewing and redesigning the existing technical curriculum to include opportunities for students to practice and develop soft skills. This is cognisant of the fact that there is no specific training for the development of soft skills, which necessitates the development of these skills through an integrated approach as part of technical training.

Activity:	Review and redesign the existing technical curriculum (i.e., all mining related learning programmes with a practical and/or theoretical component currently accredited by the MQA) to include opportunities for students to practice and develop soft skills. This

	can be done through group projects, presentations, and teamwork exercises which may emphasise the development of communication, leadership and teamwork, innovative thinking and problem solving skills.
Frequency/ Timeframe:	Review and redesigning of the curriculum to occur within the next 1 to 2 years, to be updated in line with MMS trends on a biennial basis (i.e., once every 2 years).

12.7 Recommendation 7: Accredit Course Outcomes to Improve Speed of Accreditation

The MQA should consider quality assuring learning outcomes instead of activities by setting standardised tests for short programmes as an alternative to going through the complete accreditation process for all short programmes (which is not practically possible). Learners with unaccredited short programme certificates could register directly on the QCTO/ SETA website to be assessed on the closest accredited programme covering the skills they learned in the unaccredited programme. This would bridge the gap between the high demand for short programmes and the low supply of MQA accredited short programmes.

12.8 Recommendation 8: Increase Awareness Amongst Training Providers Regarding the Latest 4IR Related Developments

To ensure that training providers can provide training on 4IR-related technologies, it is critical that they are kept up to date with emerging 4IR-related trends and the implications that these trends will have on skills training in terms of content and delivery. This may be achieved through comprehensive information sharing campaigns designed to educate and update training providers on the 4IR-related changes occurring within the sector, and the broad changes to skills training requirements that may be adopted in the future.

Activity:	Develop and conduct information sharing campaigns by hosting workshops, seminars**,** and webinars; and distributing newsletters to training providers. The information shared with training providers should contain information on 4IR-related changes occurring within the sector, such as emerging skills and occupations, and the implications these will have on training, both in terms of content as well as delivery. While workshops and seminars/webinars may be conducted on a quarterly basis, to ensure that training providers are continuously updated with the latest information, the MQA should create a communication landing page on its website specifically for training providers. All information impacting on training providers, including information on scheduled information sharing sessions, the latest

	developments in the sector regarding 4IR, changes to policies/regulations, and other relevant information should be posted on this landing page. The communication landing page should be similar to the 'communique' landing page that is currently accessible through the MQA website.
Frequency/Timeframe:	Information sharing sessions, such as workshops, seminars, and webinars, to be conducted on a bi-annual basis. On the other hand, the communications landing page to be updated on a bi-weekly (i.e., every 2 weeks) basis by the MQA's marketing and communications department.

12.9 Recommendation 9: Conduct a Review of the Resources Available to Training Providers

The MQA should commission a study aimed at conducting a review of the resources and equipment required by training providers to effectively provide 4IR-related training. This is to ensure that the training providers are well capacitated, both through technological as well as human resources, to be able to provide said training. Once this review is done, the feasibility of providing additional funding specifically for 4IR-related training based on the review may be assessed and revised accordingly.

Activity:	Commission a study to conduct a review of the resources (financial, workforce and skills) and equipment necessary for training providers to deliver 4IR-related training. The findings emerging from this study should be used to evaluate and revise existing funding allocated to training providers for resources and equipment.
Frequency/Timeframe:	Research to be conducted within the next 1 to 2 years, revision of existing funding to occur thereafter.

12.10 Recommendation 10: Develop a Strategy for Cross-Sector Collaboration

The MQA should develop a strategy aimed at forming partnerships with other SETAs that have overlapping interests. Once a strategy has been developed, the MQA should consider entering into MOUs with identified SETAs.

Activity:	Develop a strategy focused on building partnerships with other SETAs, such as the Manufacturing, Engineering, and Related Services Sector Education and Training Authority ("merSETA"), that have overlapping interests as it pertains to skills development. The strategy should contain information on specific areas of overlapping interests as well as the level of effort required from each contracted party. Overlapping interests with merSETA include occupational health and safety training, technical

	and engineering related training, as well as artisan training.
Frequency/Timeframe:	Strategy to be developed within the next year; MOUs to be entered into on an annual basis, to allow for revisions and adjustments year-on-year.

12.11 Recommendation 11: Incorporate Digital Skills into Training Programmes

To facilitate the transition from manual operations to workforces monitoring computers or operating the software controlling the technologies implemented and to meet the evolving demands of the job market, digital skills should be incorporated into training programmes.

Activity:	Introduce basic and advanced level computer courses as a mandatory requirement for the completion of mining-related qualifications. The MQA should provide resources and support to make basic and advanced level computer courses accessible and achievable for individuals pursuing mining-related qualifications. This may include the availability of grants to training providers specifically to purchase the necessary educational equipment including textbooks, online resources, and software tools, to facilitate the learning of basic and advanced computer skills. The MQA should also facilitate partnerships between more established training providers to leverage their expertise, resources, and facilities in delivering computer courses to individuals pursuing mining-related qualifications.
Frequency/ Timeframe:	Within the next 1 to 2 years.

Additionally, considering the importance of basic digital literacy, the MQA may consider incorporating a basic digital literacy module and unit standard to AET and FLC programmes as well as programmes anticipated to be most impacted by technological developments. This intervention is premised on assessing MQA funded skills programmes to determine which programmes are associated with jobs/processes/activities likely to be impacted by 4IR.

Activity:	Develop and incorporate a basic digital literacy module and associated unit standard (s) to AET and FLC programmes, as well as programmes anticipated to be most impacted by technological developments.
Frequency/Timeframe:	Within the next 1 – 2 years.

Furthermore, to increase the level of computer and digital literacy in the medium to long term, the MQA's quality assurance unit may also consider developing and incorporating a basic computer and digital literacy module and unit standard (s) as part

of the learning packs/curriculum modules that the unit already develops for training providers.

Activity:	Develop and incorporate basic computer and digital literacy modules and corresponding unit standards as part of the learning packs/curriculum modules developed for training providers.
Frequency/Timeframe:	Within the next 1 – 2 years.

12.12 Recommendation 12: Conduct Regular Monitoring of Training Programmes and Skills Initiatives

Given that the occupational and skills needs of the sector are continuously evolving, the MQA should regularly monitor the success and effectiveness of training programmes in meeting the projected skills and occupational demands. To achieve this, the MQA should clearly define a goal of regularly monitoring the success and effectiveness of training programmes in meeting the projected skills and occupational demands within the sector by establishing measurable indicators to assess the success and effectiveness of training programmes.

Activity:	Regularly conduct monitoring of the training programmes and skills initiatives in line with clearly defined goals to ensure that they remain effective and keep up with industry standards. Measurable indicators must be established prior to implementation of the training programme, so that monitoring can be done against these indicators.
Frequency/ Timeframe:	Performance achieved against established measurable indicators to be updated biennially (once every two years). Based on performance against measurable indicators, training programmes to be revised accordingly.

12.13 Recommendation 13: Establish Collaborative Forums Between Organisations and OEMs

To ensure seamless integration and optimal utilisation of resources supplied by OEMs to mining operations, the MQA may consider facilitating partnerships between OEMs and MMS organisations, through collaborative forums, to involve OEMs in the skills development process and establish a direct link between the skills required by the workforce and the technological requirements of the equipment. This proactive approach can enhance communication, understanding, and coordination between OEMs and MMS organizations in the skills development process.

Activity:	Establish collaborative forums or working groups that bring together OEMs, MMS organisations and training providers to serve as spaces for ongoing dialogue, where the specific skills needed for operating OEM-supplied equipment are discussed and aligned with training programs.

Frequency/ Timeframe:	Collaborative forums to occur bi-annually (twice a year).

12.14 Recommendation 14: Adopt and Implement the Framework for Future Skills Needs Identification

Once the Framework for Future Skills Needs Identification is adopted, the MQA should implement the framework that has been developed. The framework is envisioned to provide MQA with practical steps on how to keep abreast with the technological changes occurring in the MMS, and by extension, how to anticipate future skills needs.

Activity:	Adopt and implement the Framework for Future Skills Needs Identification.
Frequency/Timeframe:	Once off.

References

Adwok, J., 2015. Probability Sampling - A Guideline for Quantitative Health Care Research. *The annals of African Surgery,* 8 June.pp. 95-99.

African Development Bank Group, 2021. Impact of COVID-19 on Mining Case Studies of four African Countries. *Working Paper Series.*

Akinshipe, O., Aigbavboa, C., Maake, M. & Thwala, W., 2019. *Investigating Reasons for Engineering Skills Deficiency in the South African Construction Industry.* [Online] Available at: https://www.researchgate.net/publication/339446950_Investigating_Reasons_for_Engineering_Skills_Deficiency_in_the_South_African_Construction_Industry/link/5e5394e8458515072db7a818/download
[Accessed 24 November 2023].

Bowling, A., 1997. Measuring Health: A Review of Quality of Life Measurement Scales. *Medicine Health Care and Philosophy,* pp. 181-182.

Burger, S., 2023. *Emerging miners highlight impact of energy, logistics constraints on economic growth.* [Online]
Available at: https://www.engineeringnews.co.za/article/emerging-miners-highlight-impact-of-energy-logistics-constraints-on-economic-growth-2023-05-08#:~:text=RAIL%20IMPACT,mining%20sector%20compared%20to%20targets.
[Accessed 27 July 2023].

Burger, S., 2023. *Lack of energy, logistics challenges eroding emerging miners' profitability, viability.* [Online]
Available at: https://www.miningweekly.com/article/lack-of-energylogistics-challenges-eroding-emerging-miners-profitabilityviability-2023-05-05
[Accessed 8 August 2023].

Cawood, F., 2020. *Mining in the twenty-first century and its world of work: Considerations for universities offering mining qualifications,* s.l.: s.n.

Corporate Finance Institute, 2022. *Mining Industry Primer.* [Online]
Available at: https://corporatefinanceinstitute.com/resources/career/introduction-to-the-mining-industry/
[Accessed 4 May 2023].

CSIR, 2023. *STATE OF DIGITAL TRANSFORMATION IN SOUTH AFRICAN MINING INDUSTRY.* [Online]
Available at: https://www.csir.co.za/state-digital-transformation-south-african-mining-industry
[Accessed 03 May 2023].

D'Almeida, A. L. et al., 2022. Digital transformation: a review on artificial intelligence techniques in drilling and production applications. *National Library of Medicine,* Volume 119, p. 5553–5582.

Davey, R., 2023. *The Biggest Mining Technologies in 2022.* [Online]
Available at: https://www.azomining.com/Article.aspx?ArticleID=1742

Dean-Pelikan, R., 2021. *Numerical Modelling of Pillar Stress Redistribution During the Retreat Mining Process,* s.l.: s.n.

Debrah, A., Watson, I. & Quansah, D. P. O., 2014. Comparison between artisanal and small-scale mining in Ghana and South Africa: lessons learnt and ways forward. *Journal of the Southern African Institute of Mining and Metallurgy,* 114(11).

DHET, 2023. *HEMIS Data,* s.l.: s.n.

Heath, C., 2023. *What is purposive sampling?.* [Online]
Available at: https://dovetail.com/research/purposive-sampling/
[Accessed 6 September 2023].

Lane, A., Guzek, J. & van Antwerpen, W., 2015. *Tough choices facing the South African mining industry.* [Online]
Available at: http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2225-62532015000600006#:~:text=Mining%20at%20these%20depths%20also,global%20trend%20of%20resource%20nationalism.
[Accessed 27 July 2023].

Majozi, T., 2022. *Breaking New Grounds: Wits' 21st Century Digital Laboratory.* [Online]
Available at: https://www.linkedin.com/pulse/breaking-new-grounds-wits-21st-century-digital-thokozani-majozi/?trk=pulse-article_more-articles_related-content-card
[Accessed 11 May 2023].

Mandela Mining Precinct, 2021. *Modernisation: Kolomela Case Study.* [Online]
Available at: https://mandelaminingprecinct.org.za/wp-content/uploads/2021/10/Guideline-Modernisation.pdf
[Accessed 12 November 2023].

Maswanganyi, K., 2021. *THE FOURTH INDUSTRIAL REVOLUTION AND INDUSTRY 4.0 CONSIDERATIONS DURING THE PRODUCTION PHASE OF THE.* [Online]
Available at: file:///C:/Users/Joshu/Downloads/Dissertation_final.pdf
[Accessed 01 August 2023].

McKinsey & Company, 2015. *How digital innovation can improve mining productivity.* [Online]
Available at: https://www.mckinsey.com/industries/metals-and-mining/our-insights/how-digital-innovation-can-improve-mining-productivity
[Accessed 11 May 2023].

McKinsey & Company, 2019. *Putting the shine back into South African mining.* [Online]
Available at:

https://www.mckinsey.com/~/media/mckinsey/featured%20insights/middle%20east%20and%20africa/putting%20the%20shine%20back%20into%20south%20african%20mining/mck-putting-the-shine-back-into-south-african-mining-a-path-to-competitiveness-and-growth.pdf
[Accessed 27 July 2023].

McKinsey & Company, 2019. *The Future of Work in South Africa.* [Online]
Available at:
https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Middle%20East%20and%20Africa/The%20future%20of%20work%20in%20South%20Africa%20Digitisation%20productivity%20and%20job%20creation/The-future-of-work-in-South-Africa-In-Brief.pdf
[Accessed 2023].

Mckinsey & Company, 2020. *Has global mining productivity reversed course?.* [Online]
Available at: https://www.mckinsey.com/industries/metals-and-mining/our-insights/has-global-mining-productivity-reversed-course#/
[Accessed 30 August 2023].

Mckinsey & Company, 2020. *MineLens survey confirms the significant impact of COVID-19,* s.l.: s.n.

McKinsey & Company, 2020. *The mine-to-market value chain: A hidden gem.* [Online]
Available at: https://www.mckinsey.com/industries/metals-and-mining/our-insights/the-mine-to-market-value-chain-a-hidden-gem
[Accessed 10 May 2023].

Minerals Council SA, 2023. *Mining in SA.* [Online]
Available at: https://www.mineralscouncil.org.za/sa-mining
[Accessed 12 May 2023].

Minerals Council South Africa, 2018. *Skills Development in the South African Mining Industry.* [Online]
Available at:
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjUi-Hnvfj6AhXQSsAKHc9ZCKgQFnoECA4QAQ&url=https%3A%2F%2Fwww.mineralscouncil.org.za%2Findustry-news%2Fpublications%2Ffact-sheets%2Fsend%2F3-fact-sheets%2F742-skills-development&usg=AO

Minerals Council South Africa, 2019. *Artisinal and Small-Scale Mining Position Paper,* s.l.: s.n.

Minerals Council South Africa, 2021. *Facts and Figures 2021,* s.l.: s.n.

Minerals Council South Africa, 2022. *Skills Development in the South African Mining Industry,* s.l.: s.n.

Minerals Council South Africa, 2023. *Fact & Figures Pocketbook 2022,* s.l.: s.n.

Minerals Council, 2019. *People Centred Modernisation in Mining.* [Online]
Available at: file:///C:/Users/Joshu/Downloads/minerals-council-position-paper-modernisation-in-mining-factsheet-updated.pdf
[Accessed 31 July 2023].

Mining Industry Human Resources Council, 2020. *The Changing Nature of Work: Innovation,Automation and Canada's Mining Workforce,* s.l.: s.n.

Mining Technology, 2020. *Mining trucks, loaders and haulage equipment for the mining industry.* [Online]
Available at: https://www.mining-technology.com/buyers-guide/mining-loaders-trucks-haulage/
[Accessed 04 May 2023].

Mining Technology, 2021. *Cloud Computing in Mining- What's Happening.* [Online]
Available at: https://www.mining-technology.com/comment/cloud-computing-mining/
[Accessed 9 May 2023].

Mining Technology, 2023. *Diamond production in South Africa and major projects.* [Online]
Available at: https://www.mining-technology.com/data-insights/diamond-in-south-africa/#:~:text=According%20to%20GlobalData%2C%20South%20Africa,7%25%20between%202022%20and%202026.
[Accessed 11 May 2023].

Mining Technology, 2023. *Logistics solutions for the mining industry.* [Online]
Available at: https://www.mining-technology.com/buyers-guide/mining-logistics/
[Accessed 10 May 2023].

Mining Weekly, 2023. *Junior Mining: Lack of energy, logistics challenges eroding emerging miners' profitability, viability.* [Online]
Available at: https://www.miningweekly.com/article/lack-of-energylogistics-challenges-eroding-emerging-miners-profitabilityviability-2023-05-05
[Accessed 02 August 2023].

Montiea, B., 2015. *South African mining industry committed to mechanisation.* [Online]
Available at: https://www.engineeringnews.co.za/article/sa-mining-industry-committed-to-mechanisation-2015-04-03

Moolman, S., 2022. *2022 Update: Eskom Tariff increases vs inflation rate since 1988.* [Online]
Available at: https://poweroptimal.com/2021-update-eskom-tariff-increases-vs-inflation-since-1988/#:~:text=From%202007%20to%202022%2C%20electricity,money%20terms%20in%2014%20years.
[Accessed 27 July 2023].

MQA, 2020. *Sector Skills Plan for the Mining and Minerals Sector 2015 - 2020.* [Online]
Available at: https://mqa.org.za/wp-content/uploads/2021/08/MQA-SSP-Final.pdf

MQA, 2021. *Sector Skills Plan for the Mining and Minerals Sector Update for 2022-2023 Submitted by the Mining Qualifications Authority (MQA) to the Department of Higher Education and Training,* s.l.: MQA.

MQA, 2022. *FInal Consolidated SSP 2023 - 2024,* s.l.: MQA.

MQA, 2023. *MINING QUALIFICATIONS AUTHORITY STRATEGIC PLAN FOR 2020/21-2024/25,* Johannesburg: 2023.

Mungadze, S., 2021. *SA's mining sector leans on tech for business resurgence.* [Online]
Available at: https://www.itweb.co.za/content/wbrpOqgYVxW7DLZn
[Accessed 03 May 2023].

Nikolopoulou, K., 2023. *What Is Purposive Sampling? | Definition & Examples.* [Online]
Available at: https://www.scribbr.com/methodology/purposive-sampling/
[Accessed 6 September 2023].

Pols, T., 2019. *STEM Education: Science, Technology, Engineering, Maths for South African Underpriveleged Schools.* [Online]
Available at: https://www.samefoundation.org.za/stem-education-science-technology-engineering-maths-for-south-african-underprivileged-schools/#:~:text=The%20National%20Science%20and%20Technology,level%20skills%20in%20STEM%20areas.
[Accessed 2023].

PWC, 2021. *Ten insights into 4IR,* Johannesburg : PWC.

PwC, 2021. *The state of digital transformation in the South African mining industry and where it's headed ,* s.l.: s.n.

PwC, 2023. *The State of Digital Transformation in the South African Mining Industry,* s.l.: s.n.

PwC, 2023. *The state of digital transformation in the South African mining industry - Ten insights into 4IR,* s.l.: s.n.

Ramdass, N., 2022. *Project unpacks 4IR Skills Related Needs.* [Online]
Available at: https://www.miningweekly.com/article/project-unpacks-4ir-skills-related-needs-2022-04-13
[Accessed 2023].

Ramdoo, I., Cosbey, A., Geipel, J. & Toledano, P., 2021. *Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development - New Tech, New Deal: Mining policy options in the face of new technology - Executive Summary,* s.l.: s.n.

Rocketmine Industries, 2023. *Drone Mine Inspection & Survey Services.* [Online]
Available at: https://www.rocketmine.com/industries/mining/

Rodríguez-Novoa, F. & Holley, E., 2023. Coexistence between large-scale mining (LSM) and artisanal and small-scale mining (ASM) in Perú and Colombia. *Science Direct,* Volume 80.

Rungasammy, Y. & Nembudani, R., 2021. *4IR IN MINING MIGHT NOT MEAN JOB LOSSES.* [Online]
Available at: https://cms.law/en/zaf/publication/4ir-in-mining-might-not-mean-job-losses
[Accessed 11 May 2023].

SA Mining, 2022. *Is Mining Investing Sufficiently In Training And Skills Development?.* [Online]
Available at: https://businessmediamags.co.za/mining/sa-mining/is-mining-investing-sufficiently-in-training-and-skills-development/

Sharma, L., Bidari, S., Neupane, S. & Sapkota, R., 2023. Exploring the Mixed Methods Research Design: Types, Purposes, Strengths, Challenges, and Criticisms. *Global Academic Journal of Linguistics and Literature.*

Sibanye Stillwater, 2023. *Innovation & technology.* [Online]
Available at: https://www.sibanyestillwater.com/business/innovation-technology/
[Accessed 11 May 2023].

Stanz, K. et al., 2021. *Skills Needs Matrix Developed for 3 Mining Designations,* s.l.: Successful Application of Technology Centred Around People.

Statistics South Africa, 2022. *South African GDP declines by 0.7%.* [Online]
Available at: statssa.gov.za/?p=15728
[Accessed 28 August 2023].

StatisticsSA, 2019. Four facts about the mining industry.

Surucu, L. & Maslakci, A., 2020. VALIDITY AND RELIABILITY IN QUANTITATIVE RESEARCH. *Business & Management Studies: An International Journal,* 8(3), pp. 2694-2726.

Telematics, 2023. *THE RISE OF AUTONOMOUS TRUCKS IN THE MINING INDUSTRY.* [Online]
Available at: https://mixtelematics.com/us/resources/blog/autonomous-trucks-in-mining/#:~:text=An%20automatic%20haulage%20system%20is,a%20fleet%20of%20autonomous%20vehicles.
[Accessed 11 May 2023].

Trading Economics, 2023. *South Africa GDP from Mining.* [Online]
Available at: https://tradingeconomics.com/south-africa/gdp-from-mining
[Accessed 27 July 2023].

Wadula, P., 2022. *4IR - The future of mining in South Africa.* [Online]
Available at: https://issuu.com/topcomedia/docs/top500_11th_edition/s/12826371
[Accessed 04 May 2023].

Walker, T., Charles, B., Murphy, B. & Connolly, L., 2020. *Covid-19 and Mining: Coming Back Stronger.* [Online]
Available at: https://www.bain.com/insights/covid-19-and-mining/
[Accessed 9 May 2023].

Wilson, B., Austria, M.-J. & Casucci, T., 2021. *Understanding Quantitative and Qualitative Approaches.* [Online]
Available at: https://accelerate.uofuhealth.utah.edu/improvement/understanding-qualitative-and-quantitative-approac#:~:text=Quantitative%20designs%20can%20be%20experimental,around%20life%20experiences%20or%20meaning.
[Accessed 20 November 2023].

Yang, C., 2019. *The Fourth Industrial Revolution, Aging Workers, Older Learners and Lifelong Learning.* [Online]
Available at:
https://newprairiepress.org/cgi/viewcontent.cgi?article=4170&context=aerc
[Accessed 2023].

Zulu, M., Pretorius, M. & van der Lingen, E., 2021. *The strategic competitiveness of the South African mining industry in the age of hte Fourth Industrial Revolution.* [Online]
Available at: http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2224-78902021000300017
[Accessed 27 July 2023].