# Skills Needed by Engineers in the Platinum Mining Industry in South Africa

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***Abstract*--The South African platinum mining industry faces continuous challenges in terms of increased global competition, demand for productivity, skills shortages, loss of scarce technical skills due to emigration, strikes and high turnover rates. Hence, the lack of engineering skills (technical and management skills) may seriously hamper the capacity of the mining industry to ensure that productivity and safety standards are maintained. A quantitative study was conducted on skills needed by platinum mining engineers in three provinces in South Africa. A four-point Likert-type scale questionnaire ranging from strongly agree to strongly disagree was developed. The Cronbach's alpha coefficient was above 0.8, indicating high internal reliability. The population consisted of 300 engineers in platinum mines in three provinces in South Africa. A convenience sample was used; 79 engineers volunteered to complete the questionnaire. The response rate was 26.3%. A factor analysis was conducted to determine which skills of the engineers were the main concerns. The results of the study indicated that theoretical knowledge, technical skills, management skills and engineering principles were skills needed for technology-based engineering in the platinum mines under study.**

## I. INTRODUCTION

The mining industry competes with manufacturing and other local industries for scarce resources. In order to achieve the required target, based on industry demand, the focus should be on skills development programs aligned to the skills priorities of engineers. No review of mining education in South Africa would be complete without commenting on the distortions created by the government policy demanding racial segregation, which was in place from 1948 to 1994 [12].

Engineering in the minerals industry is responsible for extracting raw materials and for processing metals and minerals to be used for manufacturing. This research project was specifically aimed at identifying the skills needed by engineers in the platinum mining industry. According to the Sector Skills Plan for the Mining and Minerals Sector [21], the skills programs are clustered in line with the demands of the mining industry to assist workplaces in developing meaningful and relevant learning pathways for employees. The mining industry has met many of the employment and skills development challenges it faced over the past few years and far exceeds other industries in its commitment to training [22]. Alarmingly, found that 90% of mining engineers are over the age of 50 [18]. The required number of new mining engineers, assuming new openings and expected retirements, has been estimated by industry and other sources to be about 350 mining engineers per year. Currently, after reaching a low output of less than 100 mining engineers per year in the early 2000s, engineering graduates are now in a respectable range of over 150 per year with the expectation (looking at positive enrolment trends) that this gap will close in a few years [18].

In 2003, 61 engineers graduated, rising to 306 in 2006 [22]. The mining industry shares a limited pool of 14 000 professional engineers with all other industries. The ultimate aim of any skills program is to improve the performance that will add to organizational effectiveness and profitability [22]. Internal skills should be identified and assessed to determine competency levels and potential for ongoing training and development.

## II. LITERATURE REVIEW

The literature review provided a conceptualization of the process of determining skills deficiencies, as well as an overview of the specific skills required by engineers in the platinum mining industry in South Africa.

### *A. Skills deficiencies*

The importance of a "skills needs analysis" being conducted by professionals with the relevant expertise should be emphasized, which relates to the complexity of the skills of engineers [38]. The objectives behind conducting a skills needs assessment are to identify the organizational goals and the effectiveness of training in achieving these goals, the gaps or discrepancies between employee skills and the skills required for effective job performance and problems that may or may not be solved by training [4].

The role and attributes of the mining engineer in the life cycle of a mine need to be defined more holistically in the face of increasingly more diverse and complex responsibilities [32]. The evolution of mining engineering needs to accommodate two significant factors, namely the need to retain skills competency in its distinctive core technologies and practice, as well as the need to assume these increasingly diverse and holistic responsibilities in a sustainability context. These skills are discussed below.

- **Core technical skills**

The imminent new technologies that will transform the mining process are prompting the assumption that more focused and specialized skills sets will be needed [32]. Engineers work mostly with objects, and they usually identify with technical aspects of organizations [16].

- **Fundamental understanding of the skills sets**

Responding to today's skills shortages with short-term fixes is not enough. The more critical challenge is to address skills gaps in ways that contribute to long-term organizational success [1]. Engineers have to ensure that new processes and technologies are introduced and that current businesses are optimized and utilized. This can only be done by innovative ideas to ensure a quantum leap in performance and competitiveness. Business leaders report deficiencies in both hard and soft skills and shortages in four key areas: basic skills (which include communications and basic business acumen skills); technical and professionals skills (technology skills); management and leadership skills (covering areas such as supervision, team building, planning, decision-making and ethical judgment); and emotional intelligence skills (such as self-awareness, self-discipline, persistence and empathy) [1].

- **Developing qualities and social intelligence**

The need to produce technology-competent workers who are able to adopt advanced manufacturing strategies to local settings requires broad engineering education that will produce graduates who are highly competent in technical, analytical as well as communication skills [17]. [9] highlights the role engineering plays in society through ethics, professional responsibility, public safety and the impact of engineering on the economy, social and cultural life, environmental matters and sustainability.

- **Soft skills**

[10] views proficiency in mathematics, computation, reading, writing, the effective use of resources and information, interpersonal skills, an understanding of systems and mastering of technology and flexibility in coping with change in the workplace as the new competencies required by engineers in the current knowledge era. [20] points out that graduates often have a poor understanding of how their theoretical knowledge can be applied in practice. They also tend to be unaware of the importance of communication and people skills. This often leads to communication barriers that have effects on ore production. Apart from being skilled in the sense of having the required knowledge in a specific discipline and having the necessary technical skills required in a profession, graduates also need generic skills such as communication skills and interpersonal skills [34].

Engineering work is very complex, and technical and social skills are inextricably intertwined. This adds to the notion that engineers need to acquire a large number of technical skills, generic skills, and profound technical knowledge, of which very little is learned at university [36]. Employability skills include the effective management of resources, communication and interpersonal skills, teamwork and problem-solving skills and the acquisition and retention of a job [29]. People skills training have benefits such as providing a platform to showcase technical skills, bringing the leadership qualities, and helping personal growth [19].

Engineering is a human performance that relies on distributed expertise in which the core technical knowledge used by engineers originates from social interactions because no single person can carry sufficient knowledge [37]. The upsurge in the demand for some skills (in the field of engineering) occurs due to workers who leave the industry and the ageing profile of the workforce, which both contribute to the skills shortages in the sector. Continuing changes in work, technologies and market demands internationally lead to proportional demands for ongoing skills development. The pool of skilled employees is set to diminish, necessitating a dual strategy to curb the skills shortages in critical and scarce skills in mining. The demand for skills in the mining industry and the shortage of engineers in general call for a more innovative approach when recruiting at all levels in the organization [22].

Mining engineers who are strongly grounded in enabling technologies and systems engineering as well as in change management and innovation will be key players to success in technology transfer and process transformation for the next generation [32]. It is no longer adequate just to educate mining engineers on how to design and operate mines safely. There remains a necessity for a strong focus on the core skills, which results in the interaction between the mineral resources, mining and processing systems.

A number of challenges faced by the mining industry relate to skills shortages, in particular those of artisans, mine overseers, drillers and engineers because of the growing South African economy and demands for similar skills globally [5]. Employee training refers to "the transference of traditional job-related knowledge and skills and career development to activities, which facilitate movement within an organization, such as performance management, succession planning and promotions" [31:24]. Evidently, the need to invest and develop these skills should be similar to maintenance and improvement of the equipment and infrastructure.

Due to the rise of the new global economy, characterized by high-quality, high value-added export-oriented manufacturing and services, a key quality of human resource development is the attainment of high participation rates in general education and training, particularly the development of multi-functional skill capabilities of engineers to meet the needs of the mining sector [15].

### *B. Skills required in the platinum mining-industry*

An important task will be to reshape mining education to align with the changing needs that primarily appear to be driven by the dynamics of technological advances and sustainable development. It will also be critical to reinvigorate the human and physical resources that serve the educational process within our mining schools [32]. Mining engineering involves the design, planning and management of operations for the development, production and eventual reclamation of earth resources extraction projects. This requires a very diverse set of skills. Traditionally, the mining engineer has been viewed as the "jack of all trades and master of none" [6:366]. This lack of thorough engineering design in mining might be due to the background training of those involved in rock engineering, which does not include formal training or exposure to engineering design logic [35].

The training program for all engineers covers basic science, mathematics, computing, engineering sciences, engineering design and synthesis, and complementary studies [28]. The literature is supported by research conducted by [33], highlighting that, although a large number of engineers are in management, it is generally believed that they still lack soft skills such as communication, business management and interpersonal skills. Graduate engineers furthermore need to cultivate the ability to communicate with other people from diverse cultural backgrounds in the organization [8]. Soft skills complement hard technical skills, which are the occupational requirements and many technical activities. Engineers solve techno-economics problems through the scientific and creative use of information, which has to be compiled through report writing and presenting the information to the relevant stakeholders (the mining industry) [28].

Engineering work is very complex and technical and socials skills are inextricably intertwined. This adds to the notion that engineers need to acquire a large number of technical skills, generic skills, and profound technical knowledge and very little of which is learned at university [36]. Additional skills needed by engineers include those listed below.

- **Project management skills**

Engineers should be familiar with the basic principles of project management and organizational theory in addition to their expertise in the field of engineering [27].

- **Communication skills**

Assessment of engineering communication skills is mostly based on technical reports and oral presentation. Engineers interact with people and communicate face to face, on the phone, through emails, reports and written correspondence [36]. Young engineers are likely to spend more time listening than speaking during conversations especially in training sessions and meetings [37]. Less than 30% of their time can be ascribed to solitary technical work. [36] further notes that communication is a means for developing and maintaining a web of social relationships and shaping perceptions through information transfer.

- **Production scheduling skills**

The mine planning process is a sophisticated and integrated system, which is initiated by the operational supervisors and their production team members. This production plan is compiled and detailed in terms of meters, square meters, volumes, grades, operational cost, capital cost, recoveries and metal yields. Maximizing value is the main objective when developing long-term mine production schedules [25].

- **Environmental management skills**

Ore extraction must be performed according to an economical, safe and environmentally acceptable standard [28]. Mining operations, both open-pit and underground, typically produce large volumes of tailings deposits and waste rock piles. These may cause air pollution, water pollution and land degradation problems. Identification of the environmental risks associated with the exploitation of mines and quarries and with ore processing thus not only requires the characterization and quantification of the different types of waste, as well as a knowledge of the processes used, but also an assessment of the vulnerability of the specific environments contingent upon the geological and hydro-geological conditions and peripheral targets.

- **Leadership skills**

Soft skills comprise the ability to carry out specific tasks. These may include problem solving, personal attitudes, ethical and professional leadership, decision-making skills, general knowledge to execute tasks, analytical, mathematical and statistical skills, interpretation ability, project management, knowledge from other relevant disciplines, self-projection, and awareness of global issues [11]. The engineer position entails interaction with many different people at various levels, and a mining engineer therefore requires a sound knowledge of human resource management and this experience could lead to a management position, supervising the daily running of the mine.

## III. RESEARCH DESIGN

The research design comprised mainly of the following components:

### *A. Research problem*

The skills needed by engineers in the platinum mining industry in South Africa have not received sufficient research attention so far. There is a dire need for the specialized skills of engineers in the platinum mining industry in South Africa, in order to improve productivity, create growth and achieve job creation within this sector.

### *B. Research question*

The research aimed to answer the question regarding the most important skills needed by engineers in the platinum mining industry in three provinces in South Africa.

### *C. Research aim*

The aim of the current study was to determine the most important skills needed by engineers in the platinum mining industry in three provinces in South Africa.

*D. Research method*

A quantitative research design was utilized. [2] refer to a quantitative approach as a study whose findings are mainly the product of statistical summary and analysis. The quantitative approach focuses on a detailed description of a phenomenon [26]. In this study, the information was collected through a self-administered questionnaire. The design of a questionnaire is critical to ensure the correct research questions are addressed and that accurate and appropriate data for statistical analysis is collected [39]. A factor analysis was conducted to determine which skills of the engineers were the main concerns. Factor analysis was to reduce the data in order to identify a small number of factors that explain most of the variance observed in a much larger number of manifest variables.

*E. Research participants*

Bless and Smith [3:84] define population as the entire set of objects or people which is the focus of the research and about which the researcher wants to determine some characteristics. The population consisted of 300 engineers in the platinum mines in South Africa. The researcher used a convenience sampling method, and 79 engineers completed the questionnaire resulting in a response rate of 26.3%. The convenience sampling method relies entirely on individuals who volunteer to be a part of the sample. The participants were between the ages of 18 and 29 years (44.3%), 30 and 39 years (32.9%) and 40 years and older (21.5%). This indicates that there was high participation in the age group 18 and 29 years, followed by 30 and 39 years and low participation in the group 40 years and older. Of the participants, 75% were females and 25% males. The observed job levels indicated that the majority of the respondents were mining engineers (34.2%), followed by geologists (20.3%), chemists (19%) and least represented were metallurgists and chemical engineers (11.4%). The sample consisted of five occupational categories of engineers in the mining sector who participated in the research study, and 79 participants responded. Most of the participants had been working for less than 1 year (22.8%), 1–5 years (35.4%), 6–9 years (15.2%) and 10 years and more (25.3%).

*F. Research procedure*

The researchers collected the data using self-administered questionnaire. The researchers supplied the respondents with a detailed description of the purpose of the study and assured them of the confidentiality of their responses before they completed the questionnaires. The questionnaires were distributed to engineers in the mineral extraction section and engineers in the refinery section of the product. Participating engineers had a minimum of 1 to ten (10) years' exposure to the mining industry.

*G. Measuring instrument*

The first part of the research questionnaire focused on the demographics profile used to obtain accurate information from the respondents in respect of the following: managerial level, educational status, age, gender and years of service, while the second part was structured using the Likert format, where respondents were asked to rate each item on some response scale. A type of composite developed by Rensis Likert in an attempt to improve the levels of measurement in social research thourgh the use of standardized response categories in survey questionnaires to determine the relative intensity of different items [23]. Likert categories used in this study were "strongly agree", "agree", disagree" and "strongly disagree". The questions posed in the questionnaires were derived from a thorough literature review. A pilot study of 15 engineers was conducted for pre-testing the questionnaire to refine the questions to eliminate potential problems that respondents could have in answering the questions.

*H. Statistical analysis*

The data was presented using a combination of tabulated description using the Statistical Package for the Social Sciences (SPSS). Factor analysis indicates which factor items in the scale belong together and which ones measure the same things [26]. Data reduction is therefore possible by conducting a factor analysis. In order to measure the internal reliability of the questionnaire, Cronbach's alpha scores were calculated [30]. Cronbach's alpha value of 0.70 indicates a good reliability and acceptable reliability coefficient [3].

*I. Ethical considerations*

Before the study was conducted, ethical approval was obtained from the organizations involved. The research study posed no material hazard to any of the respondents. Anonymity and confidentiality of all the respondents were maintained throughout the study and no information can be linked back to individual participants. The confidentiality of the data was maintained throughout the study.

## IV. RESULTS

Three hundred questionnaires were distributed to the five mining houses and 79 completed questionnaires were returned. This indicated a response rate of 26.3%.

*A. Factor analysis*

The factor analysis helped to identify groups of inter-related variables to see how they relate to each other. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.648 and Bartlett's test of sphericity was significant ($p<0.05$), which indicated sampling adequacy. As a rule of thumb, KMO should be 0.60 or higher in order to proceed with a factor analysis, but a value of 0.8 or higher is desirable

TABLE 1: KMO AND BARTLETT'S TEST

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy | | .648 |
| Bartlett's test of sphericity | Approx. chi-square | 1633.498 |
| | Df | 703 |
| | Sig. | .000 |

A principle axis factor analysis (PFA) was used. The PFA is a form of factor analysis which seeks the least number of factors that can account for the common variance (correlation) of a set of variables [2]. After exploring a number of factor solutions, a three-factor solution was deemed to be the best. These factors explained 44.35% of the variance. The factor matrix with loadings is reported in table 2.

The table illustrates the three factors which were found: theoretical skills (purple), technical skills (blue), and engineering principles (green). The scores for each of the factors were created by obtaining a mean score across all the items comprising a scale. The three mean scores were knowledge and theoretical skills (1.96), technical and management skills (2.16), and engineering principles (2.75). This means that the engineering principles and management skills were the essential training priorities, supported by the theoretical knowledge gained from the tertiary institution. Figure 1 illustrates the mean scores of the factor analysis.

TABLE 2: THREE-FACTOR ANALYSIS RESULTS PATTERN MATRIX

| | Factor | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| I know how to perform metal accounting for customers. | .818 | -.208 | |
| I know how to source new equipment. | .730 | | |
| I am competent in project implementation. | .666 | .217 | |
| I know how to commission new analytical instruments. | .657 | -.239 | |
| I understand the ISO 14000 (environmental) management systems. | .657 | | |
| I know how to conduct planned maintenance. | .612 | | .283 |
| I understand the ISO9001 (quality). | .581 | | |
| I perform planned job observations. | .574 | | |
| I have knowledge of the Basic Conditions of Employment Act. | .562 | .224 | -.267 |
| I conduct research of new technology in the analytical field. | .527 | | |
| I have knowledge of health and safety regulations. | .505 | | |
| I possess knowledge of mineral beneficiation or ore preparation. | .491 | .224 | |
| I have an understanding of the treatment of effluents. | .487 | | |
| I demonstrate knowledge of statistical methods in engineering problem solving. | .464 | | |
| I have knowledge of the National Environmental Management Act. | .455 | | |
| I possess knowledge of the mechanical process for ore processing. | .405 | | |
| I have knowledge of the Mine Health and Safety Act and the Minerals Act. | .342 | | .272 |
| Engineers require combined technical and supervisory competency skills. | .341 | .263 | |
| Engineers strive to reach win-win outcomes in conflict resolution. | .323 | -.271 | .238 |
| I possess the knowledge to conduct white area investigations for mine planning. | | .679 | |
| I understand the statistical principles of geological sampling. | | .662 | |
| I am equipped with the skills to identify hazards associated with geotechnical areas. | -.274 | .644 | .407 |
| I possess knowledge of underground drilling processes. | -.359 | .611 | .359 |
| I have sufficient interpersonal skills with all levels of mining personnel. | | .607 | |
| I possess knowledge of software applications. | | .596 | -.307 |
| I have the ability to lead the mining personnel. | .214 | .533 | |
| I have an understanding of geological mapping. | | .526 | |
| I understand the statistical principles of environmental sampling. | .423 | .448 | |
| I have an understanding of mineral/ore crushing. | .272 | .287 | |
| I have knowledge of explosive prevention. | | | .868 |
| I am knowledgeable about controlled or distress blasting. | | .212 | .822 |
| I have an understanding of the haulage management process. | | .332 | .696 |
| I have a blasting certificate. | | | .682 |
| I am familiar with the basic support principles of rock engineering. | -.355 | .511 | .596 |
| I supervise construction of major engineering works. | | | .478 |
| Engineers are trained in principles and techniques of analyzing complex deformed geological terrains. | | | .416 |

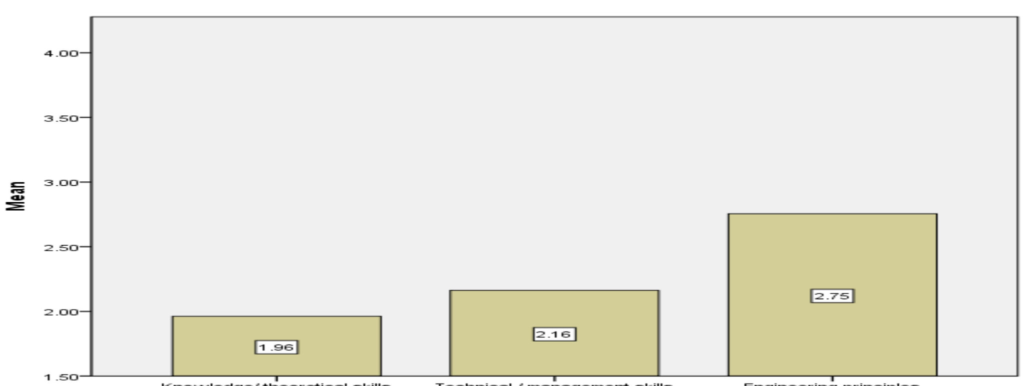


Figure 1: Factor analysis

This means that the engineering principle is a key competency in the engineering field and constant development of skills is important. The research question was to identify the most important skills needed by engineers in the platinum mining industry in three provinces in South Africa. These skills consist of theoretical knowledge such as metal accounting, project management, environmental management, supervisory skills, ISO quality standards, conflict management, knowledge of the Occupational Health and Safety Act, the Mine Health and Safety Act, Basic Conditions of Employment Act and the National Environment Act. Technical and management skills include sampling, risk assessment, drilling processes, interpersonal skills, ore crushing, chemistry, extractive metallurgy, rock blasting, production scheduling, leadership skills, communication skills, mineral separation and analysis and computer software application. Engineering principles include processes such as blasting, haulage, loading and rock engineering. The results of the study indicated that theoretical knowledge, technical skills, management skills and engineering principles are skills needed for technology-competent engineers in the platinum mines under study.

To measure the reliability of the scales the Cronbach's alpha was used as a measure of internal consistency reliability of the questionnaire. The reliability analysis was performed for each of the three factors, namely theoretical knowledge (factor 1), technical and management skills (factor 2), and engineering principles (factor 3). The knowledge and theoretical skills scale showed a high reliability of 0.886. The reliability of the technical and management skills indicated high reliability of 0.838. The reliability of engineering principles indicated a high reliability of 0.847. All items in the scales contributed well to the overall reliability.

## V. DISCUSSION

Platinum mines in South Africa experience a growing need for technical skills as they continue to mine at greater depths [24]. Minister Susan Shabangu from South Africa [13] indicated in 2012 that the industry is "reeling" from the severe shortage of skills that it requires to meet growth targets. The South African platinum mining industry faces specific challenges in terms of the delivery of projects, mine planning, overcoming ventilation constraints and complex rock engineering challenges. Platinum mines also have to meet specific physical challenges such as the increasing virgin rock temperature (2.2 ˚C) for every 1-kilometer increase in depth. Moreover, complex geotechnical conditions at these advanced depths, inadequate infrastructure and limited water resources require highly skilled engineers to come up with creative solutions to these problems. The requirement of a minimum of 10 years' experience from mining engineers when mines are recruiting new engineers, is also problematic, but [13] on average, it takes about that long for an engineer to master all the required skills, before he or she can be promoted to higher levels in the organization. This paper argues that effectively addressing the training needs of engineers in the platinum mining industry can significantly decrease the amount of time (to less than 10 years) needed for an engineer to master these skills.

The needs identifications during the needs analysis should be translated into measurable objectives [14]. Success in closing the gap between existing skills and the skills required involves three factors [7]:

- having the smallest possible gap in skills between the existing qualification and experience and the model qualification and experience;
- selecting personnel with the personal attributes needed to acquire the required skills; and
- having a system of personnel deployment that utilizes existing capabilities while providing structured opportunities to acquire the required skills.

The Skills Development Act makes provision for employers to address the technical skills shortages in the mining sector on a continuous basis. The effects of skills shortages are and will be felt in many areas, but perhaps the most significant effects in mining will be [35]:

- deterioration in safety, with an increase in the number of accidents;
- an inability to develop new projects; and
- a decline in productivity and profit as a result of the inability to operate, manage and maintain existing mines satisfactorily.

The empirical results of this study indicated that theoretical knowledge, technical skills, management skills and engineering principles are training needs of engineers in the platinum mining industry in the North West Bushveld region of South Africa.

- **Theoretical needs** include metal accounting, project management, environmental management, supervisory skills, knowledge about the ISO quality standards, conflict management, knowledge of the Occupational Health and Safety Act, the Mine Health and Safety Act, Basic Conditions of Employment Act and the National Environment Act.
- **Technical and management skills** include knowledge about sampling, risk assessment, drilling processes, ore crushing, chemistry, extractive metallurgy, rock blasting, production scheduling, mineral separation and analysis, computer software application as well as interpersonal skills, leadership skills and communication skills.
- **Engineering principles** include processes such as blasting, haulage, loading and rock engineering.

It was clear from this study, that engineering management practices could be improved by developing the management potential of every platinum mining engineer. The management of the people involved, at all levels, should be a consistent theme. Engineers work as individuals and in teams and their leadership development is therefore crucial to success. The full potential of engineers should be released. Engineering management is a specialized form of management that is required to lead engineering or technical personnel and projects successfully. Technical requirements combined with the necessary business acumen and interpersonal abilities should be developed. Technical ability should not dominate the other necessary competencies, resulting in significant opportunities for improvement in productivity and employee engagement. Today's engineering manager can exploit changing technologies, methods and markets. Innovative insights into a wide range of current engineering management issues and maintaining the importance of people management are of essence.

## VI. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Some of the mining houses refused to take part in the survey citing issues of confidentiality and a number of engineers indicated that they did not have time to complete the research questionnaire. Further research could be conducted to compare skills competencies of South African engineers against other international mining companies in determining the training priorities. Similar research could assist other industrial sectors that are experiencing skills shortages so that all sectors may learn from the research and will be able to apply recommended strategies to address skills shortages or competencies. Themes for conducting future research may include the roles of education, training and research, the effectiveness of quality standards, and the roles of institutions, cultures, government in engineering and the enhancement of employee engagement among platinum mining engineers.

## VII. CONCLUSION

In conclusion, it might be argued that the constant pressure to be productive does not leave sufficient time or resources to invest in skills development in the mining industry. From the empirical results of this study, the importance of mastery of key skills became evident. From these results, it can be deduced that no mining organization can afford to overlook the importance of proper, relevant skills development for mining engineers in their employment.

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