ISSN 1893-1170 (online edition)
ISSN 1893-1057 (printed edition)
Mineralproduksjon 8 (2018) A25-A39
MINERALPRODUKSJON
www.norskbergforening.no/mineralproduksjon

Research paper

A holistic approach to South African Mineral Resource Management pedagogy in undergraduate education

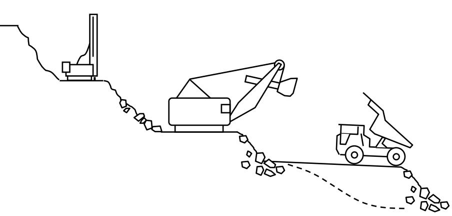
Dr. Hendrik Grobler (PhD) [1,*]

[1] Department of Mining Engineering and Mine Surveying, University of Johannesburg

* *Corresponding Author: hgrobler@uj.ac.za*

ABSTRACT

Mineral Resource Management (MRM) is a term that has been introduced in 1996 (Macfarlane , 2006) and used extensively over the last 15 years to describe various understandings of exploring, planning and managing the recovery of minerals. The MRM function is firmly established in most of the major mining houses operating within South Africa (SA) and the education system. This paper discusses the legal environment in which the field of MRM is operating and how MRM is challenged by issues such as qualification systems, resource reporting codes and attempts at job reservation by various councils and professional bodies. These issues have to be considered in the socio-economic environment in which urbanization, abandonment of mines, illegal mining and water contamination has to be considered. Recently introduced mine surveying and mining engineering qualifications at one of the three South African mining universities have been designed to address some of these issues in a sustainable and responsible manner. The qualification epistemology and the development of the pedagogic approach is aimed at developing technologists and professionals to operate in this environment with a holistic understanding of the mining value chain and the environment in which they operate to the benefit of the community. The paper concludes with some suggestions on how emerging technology be used to its full potential to address and manage the issues in a cost constrained and risk averse environment.



INTRODUCTION

South Africa (SA) is a country blessed with an abundance of mineral wealth and resources. Mining methods for these resources range from open cast mining, sea mining for diamonds (Namibia regional in other words) and ultra-deep level mining. This diverse range of mining methods is sometimes achieved using technology that in some cases has remained unchanged for at least 50 years while others are cutting-edge technologies adapted to the extreme environments of deep level mining. The selection of exploitation methods are in all cases driven by corporate requirements.

In the South African context, the abundance of natural resources must be weighed against the ever decreasing distance between local communities and mining activities. In the rapidly changing political landscape community engagement and activism is becoming more visible on a daily basis and will have an impact on future mining projects. Although this is not a unique problem in an international context, South Africa is perhaps in a unique position to address some of these issues. The three universities offering mining courses are all situated in the Gauteng province. The word Gauteng is derived from the Sotho word for "the place of gold". The city of Johannesburg was developed as a result of the extensive gold reserves mined from the late 1890's. Today in this city, urban sprawl meets mining sites and a large number of mined-out areas. The settlement around previously mined out areas and around waste and tailings dumps have created a number of challenges, including:

1. the depletion of high-grade, easily accessible reserves
2. reducing the cost of mining,
3. the need for land for housing development around mined out areas (Gauteng specifically),
4. the socio-economic impact of mine closures,
5. the rise of illegal gold mining and quarrying,
6. contamination of soil and water,
7. treatment and rehabilitation of mined-out areas, and
8. training of graduates from previously disadvantaged communities around traditional mining areas

According to the South African National Research Foundation (NRF) sustainable mining (National Research Foundation, 2016) will require the:

- development of new technologies for automation within deep underground mining environments;
- automation technologies will focus to increase safety and health of the underground work force;
- contribution to resource and energy efficiency by underground mining operations;

- contribution towards the development of technologies suitable for underground deployment between South African and German partners; and
- training of a new generation of highly qualified scientists and engineers for South African industry and the higher education sector.

THE DEFINITION OF MINERAL RESOURCE MANAGEMENT

The first reference to MRM in the South African context was found 1987 to be made by Blaauw and Trevarthen. In this paper, the authors required that a Minerals Resource management system should provide better and more accurate information on the orebody, better planning capability to exploit the resource to its maximum potential and better control of the finances, personnel and equipment used in the exploitation of the orebody. (Blaauw & Trevarthen, 1987)

In the context of South African mining, Mineral Resource Management (MRM) is a term that according to McFarlane was introduced in 1996 at the Vaal Reefs Exploration and Mining Company (Macfarlane, 2006) and used extensively over the last 15 years to describe various understandings of exploring, planning and managing the recovery of minerals. By 2006, Macfarlane defined MRM as "an integrated activity which identifies, evaluates and provides an optimal extraction plan of the mineral resource, to produce a quality product which satisfies the business objectives of the company, and the requirements of the customer, in a dynamic environment. It performs an audit and quality assurance function to ensure compliance to the business plan, and customer satisfaction in terms of quality and quantity" (Macfarlane, 2006)

The MRM term originally had the intent of describing the management of mineral resources through computerized means (Blaauw & Trevarthen, 1987). Since this time MRM has developed into an integral part of the mining process and an MRM department in various forms can be found on almost all South African mines today. Although the term MRM is firmly established, it is open to a number of interpretations and driven by a wide range of professions, including Mining Engineers, Mine Surveyors and Geologists. The International Society for Mine Surveying (ISM) defines Mine Surveying as "a branch of mining science and technology. It includes all measurements, calculations and mapping which serve the purpose of ascertaining and documenting information at all stages from prospecting to exploitation and utilizing mineral deposits both by surface and underground working." (ISM, 2017). As part of these activities, the surveyor interprets geology in relation to the economic exploitation thereof, "providing the basis of the planning, direction and control of mine workings to ensure economical and safe mining operations", including environmental issues and rehabilitation. By comparing the three different definitions a number of common trends can be observed, some of these points include:

1. integrated activity
2. orebody knowledge
3. financial control
4. optimal extraction
5. quality assurance

In the socio-economic environment in which South African mines operate, it is argued that MRM should also take into account of mine rehabilitation, reconciliation, environmental protection, involvement of local communities, the impact of mine closures and dealing with special interest groups.

EDUCATION SYSTEM

It is interesting to note that in South Africa, only one undergraduate programme, the Bachelor of Technology: Mineral Resource Management (BTech. MRM) actually attempted to formalize MRM education on an undergraduate level. The BTech MRM course was first introduced in 2007 at UJ. This 10 years after the term was first used in the South African minerals industry.

In contrast with the undergraduate position, a number of Universities offer post-graduate MRM qualifications, either as a post-graduate diploma or a fully-fledged Masters degree program. The University of the Freestate offers a two year programme Master of Science degree in Mineral Resource Throughput Management (MRTM) (UFS, 2017). The University of the Witwatersrand offers a 2 year modular certificate of competency in "Advanced Mineral Resource Management" "aimed at filling a competency gap in the field of MRM." (WITS, 2017)

The development of new suite of degrees for Mining Engineers and Mine Surveyors at the University of Johannesburg (UJ) has prompted some reflection on the relevance and content of the existing programmes. The University of Johannesburg is a comprehensive university that offers a range of qualifications from diplomas to degrees to persons in the minerals industry. During this time, van der Merwe remarked that "universities now have to produce engineers that will be able to handle the technical challenges of the future…. mines will be deeper,…Not only will there be natural hazards such as high rock stress and temperature to contend with, there will be severe organizational challenges" (van der Merwe , 2011). This statement is echoed by the CEO of Goldfields, Nick Holland who in an address declared that "the mining workforce of the future needs to be highly skilled, specialized and trained." (Holland, 2017) The result of remarks like these and industry liaison meetings were incorporated into the new curriculum that was introduced for the first time at the start of the 2017 academic year.

UNIQUELY SOUTH AFRICAN PROBLEMS?

Although a number of challenges in historic mining regions throughout the world, it is argued that the South African MRM curriculum needs to address some unique challenges, such as specific Mining legislation, population growth, socio economic trends and environmental issues. The question that needs to be fully answered is how these issues can be incorporated to develop solutions that will address our unique requirements.

The community and the Mining charter

The MRM's role in the social - and broader environment in which they operate is of critical importance in the development of mining projects in South Africa. In the past few years the impact of mining activities has converged on the broader public and communities surrounding the mines. The broad based socio economic empowerment charter for the South African Mining and Minerals industry of September 2010 (Mining Charter) describes a strategy aimed at redressing the result of past discrimination and transforming industries through the development of engineering skills of Historically Disadvantaged South Africans (HDSA), (Department of Mineral Resources, 2016). Section 3 of the Mining Charter states that non-compliance with the provision of the Mining charter and the Mineral and Petroleum Resources Development Act (MPRDA), Act 28 of 2002 "shall render the mining company in breach" and subject to the provisions of the MPRDA Section 47 (1) "…the Minister may cancel or suspend any … permission, … right, … permit …, if the holder or owner thereof (b) breaches any material term or condition of such right, permit or permission" (Department of Mineral Resources, 2002). By implication this means that mining companies are required to source bursars "reflective of the demographics" from the community in which they operate or stand to risk losing their mining license or incur substantial penalties. (Grobler H. , 2016)

Illegal mining

The need for land for housing development around mined out areas specifically in the Gauteng province and the socio economic impact of mine closure leading to illegal mining places challenges on the Department of Mineral Resources (DMR). The risk caused by illegal mining and settlement on un-rehabilitated ground contaminated by years of mining deposits, and acid mine water drainage in a region known for severe water shortages within local communities and the region at large is becoming more visible on a daily basis.

Clashes between rival gangs of illegal miners, community members endangered by unguarded mine excavations and the exposure of rescue personnel in these environment is becoming a daily occurrence. In most cases incidents are dealt with in an ad-hoc manner by police, rescue personnel and the communities depending on the point of contact at that specific incident. Cases such as these highlight in a dramatic manner how the convergence of mining activities in areas that are experiencing urban expansion can have a detrimental socio-economic impact on the community in contrast with the idea of an isolated mine with a small isolated mining community around it. Gauteng is probably one of the few major cities in the world developed over and around significant mining activities stretching over 120 years.

In some instances the current decline of formalized, full scale mining operations are resulting in the focus being shifted to secondary cleaning and pillar extraction before the ultimate abandonment of a shaft. In some of these cases these final stages of mining are plagued by illegal mining, during which the illegal miners are found to resort to methods reminiscent of original artisanal mining techniques. The formalization of informal and co-operative recycling (Bardi, 2014) and the formalization of the life cycle of a mining unit may be able to provide some solutions to this problem.

The re-mining of waste deposits has been successfully initiated in South Africa, proven by the rate at which the landmark tailings dams around Johannesburg is disappearing. The mining of municipal refuse deposits, rehabilitation and recycling of material needs a similar innovative solution that must be driven by MRM research.

Acid Mine water drainage

South Africa is an arid region with cyclical droughts and a vulnerability to climate change (Ziervogel, et al., 2014) that places tremendous pressure on the water resources of the country. The abandonment of some gold mining operations around the Witwatersrand has had an unexpected effect on the water table around

Johannesburg. As mines closed and pumping operations ceased, the water table has risen in the old mine workings. The contaminants exposed by mining has decreased the ph balance of the water table. The Sibanye Gold Mining company has established the West Rand Tailings Retreatment Project (WRTRP) will also improve management of currently affected sensitive dolomitic aquifers and water resources water treatment solutions that would purify 120 mega litres per day of surplus fissure and mineralised mine service water to a drinking water standard. (Sibanye Gold, 2017)

Responsible exploitation

In addition to the social development of a community, Hotelling was the first who developed the 'r-per cent' rule of extraction, which states that " the price of an exhaustible resource must grow at a rate equal to the rate of interest, both along an efficient extraction path, and in a competitive resource industry equilibrium" (Hotelling, 1931) This would indicate that a competitive resource owner would deplete a mineral resource at a socially acceptable rate. (Macfarlane , 2006)

TECHNOLOGY THRUSTS

According to Nick Holland, CEO of Goldfields South Africa, it takes an average of 18 years from the initial discovery to the point where gold is produced. This is in contrast with the average of 10 years a decade ago (Holland, 2017). According to Holland it is this company's strategy to halve the discovery cost and cycle time within the next seven years. At the same time it is planned that by 2026 mining waste, emissions and tailings can be halved. (Holland, 2017). According to Holland (2017), key operational challenges in the gold mining industry can be classified into four groups, namely;

1. "digital mining" including analytic capabilities of the data collected including laser scanning, telemetry and environmental conditions and being able to "mine on demand"
2. mechanization and automation, specifically remote operation of equipment
3. improving the economic extraction of low grade and residual ore bodies
4. efficient usage of energy and water supplies

The rate at which technology is developing, it is critical that the correct selection and application of technology to increase the productivity of mining companies and the efficient exploitation of the ore resource is addressed effectively. The drive for mechanization and automisation is driven by one critical component namely, positioning. Positioning technologies rather than just measuring methods, have to be developed with the help of mine surveyors. Real time Information Management Systems (RTIMS) using a combination of existing technologies such as wi-fi, indoor navigation, Radio Frequency Identification technology can be used for low cost deformation monitoring and navigation systems for mining and rescue crews.

However MRM will be seen in the future it is critical that there is operational transparency and reporting, regulated corporate governance coupled with integrated thinking into the entire spectrum of the mining operation.

A NEW EPISTEMOLOGY AND PEDAGOGY FOR MRM EDUCATION

The epistemology of the education of mine surveyors have shifted from a gold dominant model that defined the terminology and practices to a model that has started to encompass other commodities such a coal, iron and platinum, defined by different terminology, mining techniques and "corporate cultures". The calculation of reserves has historically been the domain of the mine surveyor, while variables, geological losses and structures were defined by the geologist (Diering, Andersen, Langwieder, & Smith, 2012). In the previous mines and works act, reserves had to be declared and reported to the then Government Mining Engineer. According to regulation 12.8.4 of the Mine Health and Safety Act of 1996, Act 29 of 1996, an ore reserve block plan showing the position, reference number and a tabulation of each ore reserve block area in square metres and unadjusted block value and content had to be signed off by the appointed Mine Surveyor. The regulations of this schedule of the Mine Health and Safety Act of 1996 (Act 29 of 1996, was repealed by the Minister on the 12th of November 2004 (Mlambo-Ngcuka, 2004)

Diering et al. postulated in a paper presented at the Platinum conference 2012 that a revised approach to reserve definition and mine planning is necessary. (Diering, Andersen, Langwieder, & Smith, 2012). The principle of "Ore accounting" as defined by in the textbook "South African Mine Valuation" (Storrar, 1977) taught to generations of mine surveyors and mine managers has as a result of the work proposed by Diering et al. changed the definition to the Mine Extraction Strategy (MES), Basic Mining Equation (BME), Basic Resource Equation (BRE) and Basic Financial Equation (BFE). According to Diering et al "the Business planning process has continued to evolve with advances in technology and an improved appreciation of the business value chain…" as the MRM philosophy was implemented at Anglo American Platinum that would lead to the Basic Resource to Reserve equation (BR2RE) in the cross functional business planning process. (Diering, Andersen, Langwieder, & Smith, 2012)

The pedagogy of undergraduate teaching in South Africa has been challenged during the #feesmustfall student uprising during 2016. Both the student body as well as the academic institutions has recognized the need for “Locally or regionally appropriate contextualization” coining the phrase “glocal” (ECSA, 2016). The culmination of these external factors requires transitional measures and a pedagogical shift.

It is therefore important that a full understanding of the modifying factors (mining, metallurgical, economic, legal, marketing, environmental, social and governmental) that is taken account of in the mine planning and resource estimation (Diering, Andersen, Langwieder, & Smith, 2012) needs to be nurtured within the MRM student.

The challenge is to fully understand how to develop a qualification around current trends and demands from industry. Such trends follows the economy but as the required output (graduates) lags behind, it is crucial to find ways in which to be more responsive changes within the field. The Lotka-Volterra model that describes the predator-prey relationship has been used by Bardi to describe the cyclical relationship in a “boom and bust” model (Bardi, 2014) typified by the mining industry. This principle is illustrated by the relationship reflected in graduation rates of students from the University of Johannesburg compared to the gold and platinum commodity prices. The challenge is to prevent an oversupply of graduates in “lean” times and ensure sufficient graduates during “boom” times.

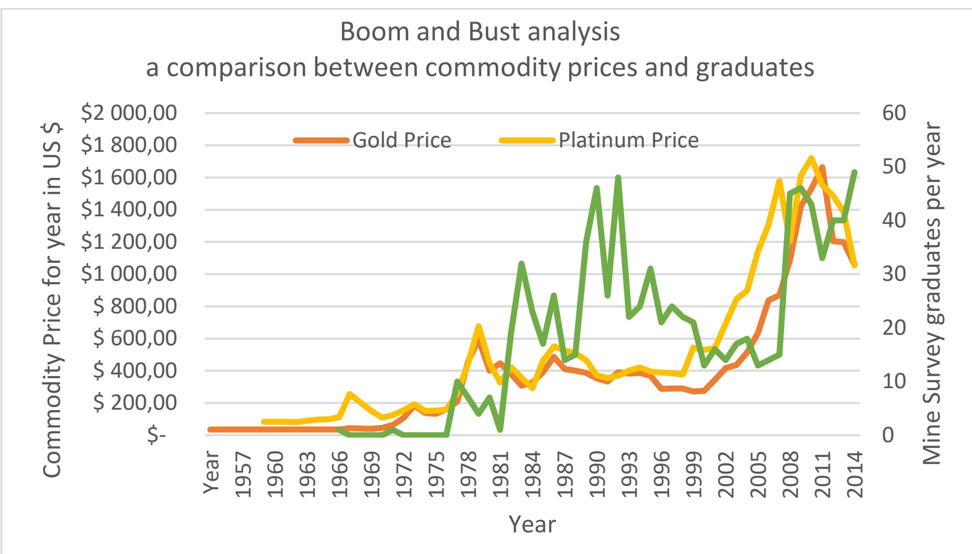


Figure 1. Boom and Bust for graduates (source UJ mine survey graduates, Grobler H.).

The graph indicates that whenever commodity prices rises it is accompanied by a demand for graduates. As graduates may already be absorbed in industry at the beginning of the boom cycle, bursaries are increased to provide more graduates. The lag time between the boom cycle and the output of these new students is approximately four to five years, by which time the boom cycle has reached maturity. This results in a larger number of graduates without employment or opportunity for internships.

ADDRESSING THE PROCESS OF UNDERSTANDING THE NEW CONTEXT OF MRM

With the changes in the student demographic profile and mining technology, the design of the new curriculum was in part an iterative process informed by the feedback from academic results, and the requirements from industry and professional bodies. Social constructivism makes assumptions based on the human experience informed by history, culture and linguistics. (Baillie & Douglas, 2014) In this context, the movement against "colonialism" must be considered a critical element of any curriculum design. Ethnography studying the influence of culture (Baillie & Douglas, 2014), in this case the mining culture, on the behavior and interaction expected of persons working in the South African mining industry as observed over an extended period of time by members of the industry liaison. Van den Akker argued that all inter related components of a curriculum should be considered in order to design a relevant new curricula. (van den Akker, 1999)

MRM content in Module groupings

In the new three year Bachelor of Mine surveying degree, a total of 84 credits (10hours per credit) is allocated to the foundational modules of Mathematics, Physics and Statistics. The core modules are arranged according to the mine value chain from Exploration through to beneficiation (table 1).

Table 1. Core modules and credits for the mine value chain.

Core modules	Credits
Mine Surveying	**49**
Mine Survey draughting	**7**
Mine Survey Practice	**22**
Geology	**28**
Mineral Reserve Evaluation	**42**
Mining	**35**
Rock Engineering	**14**
Mine Design	**63**
Beneficiation	**7**

Management and 'soft skills' account for the rest of the credits in the three year degree (table 2):

Table 2. Core modules and credits for management and 'Soft skills'.

Core modules	Credits
Active Citizenship	**14**
Engineering Management	**49**
Mineral Legislation	**14**

MRM work practice

In agreement with Drinkwater and Kelly who referred to Shuell's observation (Drinkwater & Kelly, 2003) that "what a student does is more important in determining what is learnt than what the teacher does" (Shuell, 1986). Using the argument that experience leads to reflection that in turn leads to conceptualization, an interpretivist, constructivist epistemology using ethnography as a method was used to address this question (Baillie & Douglas, 2014). Personal and participant observations of work practice formalized through industry liaison and consultation with staff and students (Grobler H. C., 2015). Some of these interventions include:

1. First year students are given a safety induction during the first academic week after registration and then taken on mine visits to an underground mining operation. The student mining forum and Women in Mining (WIM) student charter arranges additional site-specific visits to mines to see first-hand how for example gender-issues is dealt with at operational level.

2. In the new Mine Surveying degree survey workshops have now been developed as stand-alone modules in order to ensure that each individual meets the expected outcomes. In the previous curriculum, practical's was required to be completed but only contributed to a final mark. It was therefore possible for a student not to be completely competent in the practical aspects of the module and still obtain enough marks through the theory section of the module to successfully complete the module.

3. A practical module in Geostatistics and mine valuation is required from the final year Bachelor of Technology Mineral resource Management course. In this project, students are given a set of boreholes which needs to be analysed, plotted and basic statistics completed on. In preparation, students are required to perform a short investigation during the winter recess period on a mine during which time, the student must investigate

and comment on the evaluation process used at this specific mine and write a report based on these findings.

4. Based on the findings the student is expected to model the resource using kriging and determine the value of a pre-determined polygon of the ore resource. The final summative assessment in the form of a practical project is required to be in the form of a competent person's report as defined by the SAMREC code. Sections dealing with the survey datum, geology, sampling techniques, basic statistics, mining and beneficiation methods are required. The student is expected to identify errors and outliers in the data and motivate the course of action decided upon when dealing with any such identified problems. It is expected that the student take into account all the variables identified within the geology and discuss the impact thereof on the mining as well as the beneficiation processes.

5. In the final year of study, Mining Engineers and Mine Surveyors will participate in project teams to complete a mine evaluation and design based on parameters provided from the geostatistical information and mine design parameters provided. The purpose of this final exit level assessment would be not only to test the theoretical knowledge of the participants but also the soft skills of team-work, communication, gathering information from other disciplines and presentation skills.

6. Current students are expected to complete a practical portfolio of work that guides them through the entire MRM process. This format will inevitably be changed to address technological trusts a well as socio-economic issues. The principle of facilitated vacation exposure will replace the current one year work integrated learning (WIL) process that all mine survey diploma students currently undertake. The portfolio includes practical exposure in the following areas:

   a. Geology
   b. Sampling
   c. Assay
   d. Mining
   e. Surveying (measurement, control, design, layouts)
   f. Beneficiation

Laboratory exposure that includes immersive virtual reality immersion and tutorial sessions in a simulated mining environment.

CONCLUSION: HOW DOES THIS HELP IN IMPROVING THE SITUATION?

It has been remarked that in the past, the career path of Mine Surveyors would be to become Mine Managers and as such were expected to excel at the entire mining process from core logging, mine design and mine safety issues. (McDougall & Storey, 1999). McDougall and Storey postulated that the skills required by surveyors in the next millennium must include excellent communication, information technology, core mathematical, analytical, measurement, processing, presentation and management skills. (McDougall & Storey, 1999). Life-long learning skills (McDougall & Storey, 1999) must be nurtured in the undergraduate student and actively encouraged through the professional Mineral Resource Manager's career.

In order to address the issues identified in this paper, it is important to develop a robust approach to the theory and practice of teaching (pedagogy) to develop competent graduates that can enter the field of Mineral resource Management. Van der Merwe highlighted the importance of having older, experienced engineers teaching the young engineers, but in the rapidly advancing age of technology it is crucial that the trainers themselves must remain up to date with technology, trends and new methods. The only way to accomplish this is to ensure relevant mining research is conducted through the mining universities by the staff responsible for undergraduate teaching. (van der Merwe, 2011). The development of short learning programmes with OEM's on new equipment, technology and standards, deformation monitoring, scanning, resource policy and the use of drones should be implemented to educate existing "old-school personnel" (van der Merwe , 2011).

Research conducted in finding of mining alternatives, re-use of mined out and rehabilitated areas, monitoring, safety and sustainability is needed to develop a better understanding of the new requirements of mineral Resource Management. Cawood highlighted the importance of exploring for new resources that may be in unconventional, remote locations not accessible by current technologies (Cawood, 2014). With mechanization, workers must be equipped with the correct skills to operate new technologies that will include real-time decision making. Technological breakthroughs developed in the mining of coal on an industrial level in the past century contributed to the development of society as a whole (Cawood, 2014). Similarly, the developments made in the mining industry now and in the future should contribute to the advancement of society as a whole.

In order to develop the correct pedagogy for MRM it is necessary to understand how the definition of MRM has evolved and what the impact thereof is on Mine Surveying- and Mining Engineering students. It is important that any changes to the curriculum should only be introduced after consultation with industry and

Original Equipment Manufacturers (OEM's) in order to ensure that technology thrusts such as 3D printing, autonomous machinery, building information management (BIM) and indoor navigation are realistically addressed.

REFERENCES

Baillie, C., & Douglas, E. P. (2014, January). Confusions and Conventions: Qualitive research in Engineering education. Journal of Engineering Education, 1-7.

Bardi, U. (2014). Extracted, how the quest for mineral wealth is plundering the planet. USA: Chelsea Green Publishing.

Blaauw , F. J., & Trevarthen, N. C. (1987). Mineral Resource Management: An Overview of an Integrated Graphics Based System President Brand Mine,. Twentieth International Symposium on the Application of Computers and Mathematics in the Minera (pp. 255-264). Welkom, South Africa: SAIMM.

Cawood, F. (2014). Keynote adress: Mining education and research as a strategic driver for future mining. Southern African Institute for Mining and Metallurgy, 6th International platinum conference.

Department of Mineral Resources. (2002). Mineral and Petroleum resources development act, Act 28 of 2002. Republic of South Africa: Department of Mineral Resources.

Department of Mineral Resources. (2016, April 15). Reviewed broad based black economic empowerment charter for the South African mining and minerals industry, 2016. Government gazette of the Republic of South Africa, 610(39933).

Diering, D. H., Andersen, D. C., Langwieder, G., & Smith, G. L. (2012). The Basic Resource Equtions - a new approach to the definition and reconcilliation of mineral resources and reserves at Anglo American Platinum Ltd. Southern African Institute of Mining and Metallurgy, 557-576.

Drinkwater, D., & Kelly, G. (2003). a national curriculum in Australian minerals education: New generation flexible delivery undergraduate courses. Johannesburg: South African Institute of Mining and Metallurgy APCOM.

ECSA. (2016). Implementation of decolonisation of knowledge – Engineering and Engineering Technology Programmes. Johannesburg: Engineering Council of South Africa Deans Forum.

Grobler, H. (2016). Connecting Education and Industry" a South African Mine Surveying perspective. Johannesburg: not published.

Grobler, H. C. (2015). An integrated approach towards a new suite of qualifications within the Mine Surveying industry. 3rd Biennial conference of the South African Society for Engineering Education. Durban: South African Society for Engineering Education (SASEE).

Holland, N. (2017). The mine of the future. A presentation at the 120 year celebraton of the WITS School of mines. Johannesburg: Goldfields South Africa. Retrieved from https://www.goldfields.co.za/pdf/presentations/2017/mine_of_the_future_20170323.pdf

Hotelling, H. (1931). The economics of exhaustible resources. The Journal of political economy, 137-175.

ISM. (2017, March 12). Mine Surveying. Retrieved from ISM - The International Society for Mine Surveying: http://www.ism-minesurveying.org/mine-surveying.html

Macfarlane , A. S. (2006). Establishing a new metric for mineral resource management. The Journal of The South African Institute of Mining and Metallurgy, 187.

McDougall, K., & Storey, B. (1999). Mine Surveying education - a model for the future. University of Southern Queensland.

Mlambo-Ngcuka, P. (2004, November 12). Notice of Repeal. Government Gazette, pp. 17,18.

National Research Foundation. (2016, August 1). a-germany-bilateral-research-chair-sustainable-natural-resource-management-. Retrieved from National Research Foundation: http://www.nrf.ac.za/division/funding/sa-germany-bilateral-research-chair-sustainable-natural-resource-management-%E2%80%93-safe

Shuell, T. J. (1986). Cognitive Conceptions of Learning . Review of Educational Research Vol. 56, No. 4, pp. 411-436.

Sibanye Gold. (2017, February 14). Acid Mine drainage. Retrieved from www.sibanyegold.co.za: https://www.sibanyegold.co.za/component/jdownloads/.../377-acid-mine-drainage

Storrar, C. D. (1977). South African Mine Valuation (1987 ed.). (C. D. Storrar, Ed.) Johannesburg: Chamber of Mines of South Africa.

UFS. (2017, February 12). Academic information MSC Mineral Resource Management. Retrieved from University of the Freestate: http://www.ufs.ac.za/natagri/departments-and-divisions/geology-home/academic-information/msc-(mineral-resource-management

van den Akker, J. (1999). Principles and methods of development research. In Design approaches and tools in education and training (pp. 1-14). Boston: Kluwer Academic.

van der Merwe , J. N. (2011). Future of the South African mining industry and the roles of the SAIMM and the Universities. Journal of the Southern African Institute of Mining and Metallurgy vol.111 ISSN 2225-6253.

WITS. (2017, February 12). certificate programme. Retrieved from Wits Enterprise: wits-enterprise.co.za/c/certificate-programme-in-mineral-resource-management-mrm

Ziervogel, G., Mark, N., Archer van Garderen, E., Midgley, G., Taylor, A., Hamann, R., . . . Warburton, M. (2014). Climate change impacts and adaptation in South Africa. Wiley on-line Journal. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/wcc.295/full