Hands On Mining

REPORT ON EVALUATION OF CHAMBER OF MINES ROCK MECHANICS CERTIFICATE IN TERMS OF NATIONALLY ACCEPTED CRITERIA

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1 SCOPE OF WORK

As requested by Ms J de Leeuw of the Mining Qualifications Authority, this report assesses the regulatory background to rock engineering qualifications in South Africa, evaluates the appropriate level of the present Chamber of Mines Rock Mechanics Certificate and presents an outline of the proposed curriculum for a potential replacement to the Rock Mechanics Certificate.

2 INTRODUCTION

During the last fifteen years, several events have shaped the way that education and registration of professionals in engineering will be implemented and regulated. Firstly, the South African Government passed new legislation concerning higher education and registration of professionals. In addition, mining laws began to change with the introduction of the Health and Safety Act, which has a significant influence on rock engineering practices in the mining industry.

The laws that affect the engineering profession in particular, with special reference to mining appear below:

- Engineering Profession of South Africa Act No. 114 of 1990
- South African Qualifications Authority Act No. 58 of 1995
- Mine Health and Safety Act No.29 of 1996
- The Higher Education Act No. 101 of 1997
- Engineering Profession Act No. 46 of 2000

These acts will shape the engineering profession in South Africa for years to come. The Engineering Council of South Africa (ECSA), mandated to regulate the engineering profession in South Africa, is the successor to SACPE (The South African Council of Professional Engineers), which was established in 1969. This organisation underwent several changes to meet the demands of the profession until 1990, when it was renamed the Engineering Council of South Africa after the promulgation of the Engineering Profession of South Africa Act No. 114 of 1990. ECSA is now a statutory body established in terms of the Engineering Profession Act No. 46 of 2000.

Because of the untiring efforts of Professor HE Hanrahan, ECSA was admitted as a full signatory of the Washington Accord in November 1999 in Sydney, Australia. This means that guidelines, standards, and accreditation procedures employed by ECSA are in line with those of the other signatories, and international best practice. Engineering degrees conferred by South African universities that have ECSA accreditation are therefore acceptable in the eight signatory countries, namely the United Kingdom, Ireland, the USA, Canada, Australia, New Zealand, Hong Kong China, and South Africa. This accord is important because it confers international acceptability on accredited engineering degrees, forces ECSA to remain abreast with international developments, and ensures that the accreditation process remains internationally acceptable.

In parallel with the above events, the South African Qualifications Authority Act No. 58 of 1995 established the South African Qualifications Authority (SAQA). Under Section 14 of the act, SAQA has set up a National Qualifications Framework (NQF), to provide for the registration of national standards and qualifications. The regulations under the act outline twelve organising fields, of which mining falls into Field 06: *Manufacturing, Engineering and Technology*. The regulations are made with the approval of the Minister of Education in consultation with the Minister of Labour. Presently, representative committees or Standards Generating Bodies are developing qualifications and unit standards for registration with the NQF. Although rock engineering qualifications and unit standards for levels 1 – 4 have been registered with the NQF, there is still much work to be done at Levels 5 to 10, the *Higher Education and Training Band.*

The Higher Education Act No. 101 of 1997 set up the Council on Higher Education, which performs quality assurance on all higher education programmes through the Higher Education Quality Committee. The act specifically states that quality assurance must be performed against standards registered within the National Qualifications Framework (NQF), which is defined in Chapter 2 of the regulations under the South African Qualifications Authority Act No. 58 of 1995. The act provides that the Higher Education Quality Committee may, with the concurrence of the Council on Higher Education, delegate any quality assurance functions to other appropriate bodies capable of performing such functions. For engineering in particular, a process underway since 2000 will set up a Memorandum of Understanding between the Higher Education Quality Committee and the Engineering Council of South Africa (ECSA), which has the appropriate training programme accreditation mechanisms (Hanrahan, 2000). This agreement means that ECSA accreditation of university B Eng degree programmes and technikon B Tech and N Dip programmes will be recognised by the Department of National Education.

Certificated engineers can come from all three above streams as well as the artisan trades, or they can obtain a training college education followed by the government engineering certificate examinations. The category of certificated professional engineer is in the process of being incorporated under the ECSA umbrella of engineering registrations, bringing the total to four, as summarised in Table 1 below.

Table 1: ECSA Registration Categories for Practising Engineers

Category	Abbreviation	Qualification
Professional Engineer	Pr Eng Pr Ing	B Eng, BSc Eng
Professional Engineering Technologist	Pr Tech Eng Pr Teg Ing	BTech
Professional Certificated Engineer	Pr Cert Eng Pr Dipl Ing	N Dip, Government Certificate
Professional Engineering Technician	Pr Techni Eng Pr Tegni Ing	N Dip

The Mine Health and Safety Act No. 29 of 1996 is of particular relevance to rock mechanics certificate holders in industry, because section 9(2) requires that an employer must implement a Code of Practice on any matter affecting the health and safety of employees, or any other person who may be directly affected by activities at the mine, should the Chief Inspector of Mines require it. In the field of rock engineering, the Chief Inspector of Mines has required a Code of Practice for rockfalls and rockbursts in the tabular metalliferous mines (Department of Minerals and Energy, 2001, and Department of Minerals and Energy, 1996a), and a code of practice for rockfalls in the coal mines (Department of Minerals and Energy, 1996b).

Both the DME guidelines issued in 1996 contain a definition of a *suitably qualified rock engineering practitioner* as *a person who is at least in possession of a Chamber of Mines Certificate in Rock Mechanics*. Both 1996 documents refer to a *rock engineering consultant*, who must be employed to review the draft Code of Practice, but only the tabular metalliferous mines guideline contains a definition. A consultant was defined in (DME, 1996a) as *A professional engineer or professional natural scientist specialising in Rock Engineering and practicing, or a graduate possessing a Chamber of Mines Certificate in Advanced Rock Engineering, who has sufficient experience in rock engineering practice in the mining industry that he is able to advise management on strategic decisions that affect the industry, and has sufficient theoretical knowledge to be able to understand and implement new research findings in industry*.

Further regulatory intervention was promulgated in an amendment to the regulations pertaining to the Mine Health and Safety Act issued in 2001. Section 14 of the regulations now stated that:

14.1 *At every underground mine where a risk of rock burst or rock falls exists, and at every other mine where a significant risk of rock burst or rock falls exists, the employer –*

(*mine design, planning and operations*)

14.1.8 *must ensure that the input of a competent person is properly and timeously considered and integrated into mine design, planning and operations.*

According to the schedule for the regulations:

A) *For purpose of Regulation 14.1.8 competent person means a person who is at least in possession of either the Chamber of Mines Certificate in Rock Mechanics (Metalliferous Mines) or the Chamber of Mines Certificate in Rock Mechanics (Coal Mines), whichever is appropriate for the type of mine concerned.*

The implementation of all the above laws has led to the question of more widespread regulation of engineering practices in the mining industry. With the *Identification of Engineering Work* complete (ECSA, 2006), it means that rock engineering, in one form or another will come under the umbrella of

ECSA, eventually leading to the compulsory registration of all practitioners, both in the mining industry and elsewhere.

Current indications are that rock mechanics practitioners will be registered within the “professional route” (i.e. Pr Eng, Pr Eng Tech, Pr Techni Eng), rather than within the “certificated route” (i.e. Pr Cert Eng). The primary reason for this appears to be that the Certificated Manager / Certificated Engineer has additional emphasis on the legal responsibility, as apposed to the more technical nature of the rock engineer’s role. The content of the various Chamber of Mines Certificates in Strata Control / Rock Mechanics / Advanced Rock Engineering were evaluated in a previous report (Handley, 2004). This was also linked together with the work requirements of the different types of rock engineering / strata control practitioners. Part of the original work has been included as Appendix A.

Currently, there is no stand-alone rock engineering curriculum offered at tertiary level by any institution. Several institutions do offer rock mechanics and soil mechanics as undergraduate modules required for graduate qualifications in mining engineering, civil engineering and engineering geology, while two offer post-graduate modules in rock engineering.

3 EVALUATION OF CURRENT QUALIFICATION

The vision behind this document is to produce competent rock engineering practitioners who – within the constraints of the law, economic factors, and environmental factors – will make a positive and lasting contribution to safe mining operations, thus helping to ensure the long term stability, growth and prosperity of the South African Mining Industry. The general objective of the Rock Mechanics Certificate is to provide a benchmark qualification to the mining industry. Because this is an engineering qualification, its replacement should be registerable by ECSA, and it should therefore follow the general guidelines and educational outcomes provided by ECSA.

The structure is based on the work that rock mechanics practitioners perform on the mines, as provided by industry in the form of job descriptions for the strata control, rock mechanics practitioner, and rock mechanics supervisor / manager levels. These were compiled into generic job descriptions by Handley (2004) and then agreed to by SANIRE. All three generic industry job descriptions appear in Appendix A in order to assist the reader to view the rock mechanics practitioner position in its proper perspective. Furthermore, SANIRE, in conjunction with ECSA, has evaluated the level of the rock mechanics practitioner’s work, and found it to be largely on level 2, i.e. in which the description of engineering activities and problems is termed “broadly defined to well defined”. The result of this evaluation is not repeated here because of the excessive size of the data table, but may be obtained from SANIRE.

The selection of a suitable replacement qualification for the present rock mechanics certificate takes into consideration the following:

- The ECSA requirements;
- Bloom's Taxonomy of Educational Objectives (Appendix B);
- The job description of the rock mechanics certificate holder (Appendix A);
- The often-unacknowledged foundation material and knowledge required to obtain the rock mechanics certificate (mathematics, mechanics, physics, geology, mining, survey, mineral economics, ventilation, etc.).

It is clear that the rock mechanics certificate should be a qualification with a level similar to that of the N Dip, since this is the minimum level that the rock mechanics practitioner is required to work to. Based on the above, the author is of the opinion that the **closest compatible qualification to the present Chamber of Mines Rock Mechanics Certificate is the 360-credit National Diploma.**

4 STRUCTURE OF PROPOSED REPLACEMENT QUALIFICATION

Two possible replacement options for the present rock mechanics certificate are envisaged, namely:

- A 360-credit replacement rock mechanics certificate, to be offered at an NQF level 6 (a new qualification to be registered with SAQA), or
- A possible area of specialisation within the existing National Diploma, with the basic content of the qualification remaining the same, but with specialisation within the discretionary credit allowance.

Table 2: Minimum curriculum content by knowledge area specified by ECSA

Knowledge Area	**Minimum curriculum content (credits*)**			
	B Eng	**B Tech**	**N Dip**	**COMRMC****
Mathematical Sciences	56	40	30	30
Basic Sciences	56	20	20	40
Engineering Sciences	168	120	90	90
Engineering Design	67	50	20	20
Computing and IT	17	40	30	30
Complementary Studies	56	20	20	20
Subtotal	**420**	**290**	**210**	**230**
Discretionary	140	190	150	130
Total	**560**	**480**	**360**	**360**

Notes: * The credit is defined by SAQA, or South African Qualifications Authority, to represent 10 notional activity hours by the student, including lecture attendance, practicals, assignments, study, and examinations.

** Assumed / proposed curriculum content for rock mechanics certificate (COMRMC = Chamber of Mines Rock Mechanics Certificate) and replacement certificate

It is proposed that the replacement rock mechanics certificate covers all the knowledge areas at the same level as the N Dip, with the exception the basic sciences, where the addition of geology doubles the number of credits required. Table 2 lists the credit requirements for the three basic tertiary qualifications, and compares these with the proposed requirements for the rock mechanics certificate. In order to remain comparable to the N Dip, the 150 discretionary credits have been reduced to 130. Geology is considered fundamental to the rock mechanics certificate, and that is why it should be taught under the basic sciences knowledge area, rather than at a later specialisation stage under the discretionary credits.

Further details of each module in the qualification should be based on the following:

- All the modules in the six knowledge areas should be standard engineering modules as they are offered by the tertiary institutions either through contact courses or distance learning courses;
- There should be introductory rock mechanics and seismology given under the engineering sciences heading, and these courses should be compulsory for other specialists such as mine surveyors, geologists, and mine ventilation practitioners studying for a diploma;
- The discretionary portion of 130 credits should differentiate the diplomat undergraduate from mainstream engineering by concentrating on more advanced rock mechanics, mine layout and design, elementary numerical modelling, more advanced communication and report writing, and more advanced mining-induced seismicity.

This approach means that the trainee rock mechanics practitioner will get all or nearly all the basic science and engineering knowledge in the defined knowledge areas, before he/she becomes more differentiated towards rock engineering through the discretionary courses.

5 VERTICAL QUALIFICATION PROGRESSION

The replacement qualification (whether through the specialised National Diploma route or the replacement Rock Mechanics Certificate route) will be a recognised level 6 qualification. Its holder will be thus able to progress to higher level qualifications through existing channels at tertiary institutions.

Based on the current Higher Education Qualification Framework as shown in Appendix C, vertical progression could be achieved via an Advanced Diploma on level 7 (which would be a likely replacement for the current Chamber of Mines Advanced Rock Engineering Certificate), followed by a Postgraduate Diploma on level 8. These could then lead into the usual Masters and Doctorate degree programmes. Following the above strategy provides a full vertical progression of qualification from level 2 through to level 10. It also allows for professional registration of rock engineering practitioners with ECSA on the appropriate level of qualification.

6 CONCLUSIONS

A proposed qualification outline based on ECSA accreditation requirements has been completed for the rock mechanics certificate. This qualification will open up a continuous pathway in the NQF to progress from Level 2 to Level 10, and from Level 6, will enable registration with ECSA as a Professional Engineering Technician if the holder does not hold any other tertiary educational qualifications. Holders with the relevant tertiary qualifications will simply register with ECSA in the appropriate category.

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APPENDIX A
INDUSTRY JOB DESCRIPTIONS AND EVALUATIONS FOR ROCK MECHANICS PRACTITIONERS

A1 Strata Control Certificate Holder

The Strata Control Certificate Holder (SCCH) performs mainly an observing, quality control, and reporting function, together with routine functions associated with short term mine planning. In what follows, a generic summary of the main activities of the strata control certificate holder together with an estimate of associated cognitive levels appears in Table A1 below.

The SCCH should visit the mining operations four times a week, or 17 times per month, spending the remaining 6 shifts in the office for mine planning and other routine activities. Activities 1 to 8 are performed mainly in the mine operations (i.e. underground or in the open pit), and the remainder in the office. Activities 2, 4 and 8 are performed daily, and are estimated to take up 60% of the SCCH's operational shift time. The remaining activities are not performed daily, and are estimated to take up the remaining 40% of shift time. Using this to weight the average cognitive levels (assuming that each activity enjoys an approximately equal weighting in the *daily* and *less often than daily* categories) we find that the average cognitive levels required for the work are 80% knowledge, 17% comprehension and 3% application.

Table A1: Generic Job Description for the Strata Control Certificate Holder

No.	Activity	Cognitive Level
1	Observe and report abnormalities in rock mass structure underground or in open pit slopes, and recommend mine standard solutions to reduce the hazard posed by them	70% Knowledge 20% Comprehension 10% Judgement
2	Ensure that support standards are met in all producing excavations on an ongoing basis, point out support systems that are not to standard, and advise on ways to bring them to standard	80% Knowledge 20% Comprehension
3	Check that permanent support in long-life excavations remains in a serviceable condition, and request its replacement in areas where it has corroded, or has been damaged by rock mass movement or mining activity	80% Knowledge 20% Comprehension
4	Monitor implementation of mine standard support systems for the respective excavation types and respective geotechnical areas on the mine	100% Knowledge
5	Monitor implementation of mine standard support systems for abnormal situations underground and in open pits, e.g. special areas	70% Knowledge 20% Comprehension 10% Judgement
6	Monitor performance of pillars and optimised mine layouts implemented in the mine plan	50% Knowledge 50% Comprehension
7	Assist with instrumentation installation and monitoring	100% Knowledge
8	Monitor blast damage in all producing and developing excavations, and advise on ways to reduce the damage where appropriate	70% Knowledge 20% Comprehension 10% Application

No.	Activity	Cognitive Level
9	Assist with routine seismic monitoring (where applicable)	100% Knowledge
10	Ensure that all mining excavations are made in their planned positions, and at their planned rate (i.e. ensure that the mine plan is implemented)	100% Knowledge
11	Perform routine risk assessments on all mine excavations	90% Knowledge 10% Judgement
12	Perform routine rock mechanics computer program runs for use as input into mine planning where applicable	100% Knowledge
13	Produce routine written reports on activities using standard mine formats for input into mine planning, task allocation, and record keeping	50% Knowledge 30% Comprehension 5% Application 5% Analysis 5% Synthesis 5% Judgement

Activities 9 to 13 are performed in the office, and assuming that they all enjoy equal weighting, yield 88% knowledge, 6% comprehension, 1% application, 1% analysis, 1% synthesis, and 3% judgement. Weighting the office and operational components on a 17:6 basis we obtain the overall result of 82% knowledge, 14% comprehension, 2% application, 1% for analysis and synthesis combined, and 1% for judgement.

The overall result shows that the SCCH relies mainly on knowledge to perform the work, setting the qualification for the work at NQF level 4. Most of the work is based on local knowledge, using mine standards and the mine Code of Practice as guidelines. Currently, the SCCH requires at least matric and a Strata Control Certificate to perform the work. Much of the communication and all the modelling will be done using a computer, so the SCCH must be sufficiently computer literate (having at least a rudimentary knowledge of operating systems, and good knowledge of the user interfaces for a word processor, spreadsheet, presentation program, and the numerical models in use) to perform these functions efficiently.

A2 Rock Mechanics Certificate Holder

The Rock Mechanics Certificate Holder (RMCH) provides a mine design and optimisation service and solutions to rock engineering problems with the purpose of maximising safety, hence profitability, of his/her area of responsibility. This work is much more engineering-like than that of the SCCH, who provides mainly a support service to the RMCH. It requires higher cognitive domains, through higher degrees of application, analysis, synthesis, and judgement. A generic summary of the main activities of the rock mechanics certificate holder appears in Table A2 below.

Table A2: Generic Job Description for the Rock Mechanics Certificate Holder

No.	Activity	Cognitive Level
1	Visit problem areas on the mine, observe and analyse the situation, and report on the problem with recommendations for its solution, using rock mechanics theory, numerical modelling, and any other tools that may be necessary	Knowledge 30% Comprehension 20% Application 20% Analysis 20% Synthesis 5% Judgement 5%
2	Design, test, optimise, and implement support systems based on new products, or new mining strategies for problem areas, for safety and cost-effectiveness	Application 50% Analysis 30% Synthesis 10% Judgement 10%
3	Where applicable, work alongside the mine seismologist in evaluating the effectiveness and risk of the new implementations from seismic data	Application 50% Analysis 30% Synthesis 10% Judgement 10%
4	Design and optimise support systems or mining strategy for special areas (e.g. pillar extraction), problem areas, and for new mining areas, reviewing performance and modifying if necessary	Analysis 60% Synthesis 20% Judgement 20%
5	Manage monitoring and laboratory tests for input into analyses and designs	Application 40% Analysis 60%
6	Supervise SCCH(s) in carrying out duties, and play leadership, mentorship, and training roles to SCCH's in department	Knowledge 40% Analysis 30% Judgement 30%
7	Design and supervise tests for new equipment, methods, materials, products, and techniques that may benefit safety and reduce cost	Application 30% Analysis 30% Synthesis 30% Judgement 10%
8	Supervise routine risk assessment carried out by the SCCH, and carry out risk assessments for new support systems, mine layouts, and the implementation of new methods, products, and techniques	Knowledge 30% Comprehension 30% Application 30% Judgement 10%
9	Assist the Advanced Rock Engineering Certificate Holder in rock related accident enquiries, and keep a statistical database for input into the Code of Practice	Knowledge 30% Comprehension 20% Application 30% Analysis 20%

No.	Activity	Cognitive Level
10	Participate and provide input into monthly mine planning, and approve the six-month and two-year mine plans from a rock mechanics point of view	Knowledge 20% Comprehension 20% Application 30% Analysis 30%
11	Perform a training function in rock mechanics for line management, supervisors, and labour	Knowledge 80% Judgement 20%
12	Maintain and update mine standards based on implementation of new mining strategies and methods, and new support systems	Analysis 80% Judgement 20%
13	Attend technical symposia and conferences, and play a role in organising local and regional technical seminars and meetings	Knowledge 40% Comprehension 40% Judgement 20%

The rock mechanics certificate holder should visit mining operations twice a week, or 8 times per month, spending the remaining 15 shifts on surface for mine planning, report writing, design, and analytical activities. Activities 1 to 8 are performed partly at the working face, and partly in the office, with the remaining activities being performed in the office. Activities 1 to 7 are performed on an ongoing basis, and are estimated to take up 80%, or 18 shifts of the RMCH's time, while activities 8 to 12 take up the remaining 20%, or 5 shifts per month. Using these estimates to weight the average cognitive levels (assuming that each activity enjoys an approximately equal weighting in its respective grouping) the final result is 18% knowledge, 9% comprehension, 22% application, 31% analysis, 8% synthesis, and 12% judgement.

This overall result indicates that the RMCH relies mainly on application and analysis to perform the work, using engineering principles and engineering problem solving methods. Designs tend to be based on previous experience and accepted industry practice, explaining the low level of synthesis. Judgement tends to be relatively high because of the many unknowns and unpredictabilities in rock mechanics. Much of the communication and all the modelling will be done using a computer, so the RMCH must be sufficiently computer literate, having at least a rudimentary knowledge of operating systems, and good knowledge of the user interfaces for a word processor, spreadsheet, presentation program, and the numerical models in use, to perform these functions efficiently. The RMCH will also be familiar with statistical analysis, and "what-if" comparative numerical modelling without having to be completely knowledgeable of the inner workings of the numerical model itself, although a practical working knowledge of its shortcomings and limits will be required.

A3 Advanced Rock Engineering Certificate Holder

The Advanced Rock Engineering Certificate Holder (ARECH) manages the rock engineering function for the mine with the purpose of maximising safety and productivity. This work has much in common with management of any engineering function, and the ARECH should be well versed in all aspects of rock mechanics, in order to provide the correct guidance and direction to the rock engineering support service. It requires similar cognitive domains to those of the RMCH, with a significantly higher degrees judgement, because of the management function. A generic summary of the main activities of the advanced rock engineering certificate holder together with an estimate of associated cognitive levels appears in Table A3 below.

Table A3: Generic Job Description for the Advanced Rock Engineering Certificate Holder

No.	Activity	Cognitive Level
1	Maintain and direct the rock engineering strategy for the mine	Knowledge 20% Comprehension 20% Application 20% Analysis 20% Synthesis 10% Judgement 10%
2	Where applicable, manage the mine-wide seismic system, or manage a seismic monitoring contract on behalf of the mine	Knowledge 50% Comprehension 30% Judgement 20%
3	Coordinate ongoing risk assessment of mine workings using operation observations, mine plans, modelling results, and data from instruments (including seismic systems, where applicable) as inputs	Application 30% Analysis 30% Synthesis 10% Judgement 30%
4	Communicate threatening or hazardous situations to management, suggesting solutions, and coordinating implementation of solutions	Application 40% Analysis 40% Judgement 20%
5	Coordinate trials of new products, techniques, methods, and materials, often in cooperation with outside agencies, reporting on the trials and making recommendations on the results	Application 30% Analysis 30% Synthesis 30% Judgement 10%
6	Ensure that all mining strategies and plans are technically defensible, given all information at hand	Application 40% Analysis 40% Judgement 20%
7	Establish and maintain the mine Code of Practice for rockbursts (where applicable), rockfalls, and slope failure (where applicable)	Application 30% Analysis 30% Synthesis 30% Judgement 10%
8	Coordinate approval of six-month and two-year mine plans, and approve five-year mining plan	Knowledge 20% Comprehension 20% Application 30% Analysis 30%

No.	Activity	Cognitive Level
9	Coordinate and manage liaison between rock engineering department and line management	Knowledge 20% Comprehension 20% Application 30% Analysis 30%
10	Coordinate and perform a training and mentoring function in rock mechanics for rock mechanics staff, line management, supervisors, and labour	Knowledge 80% Judgement 20%
11	Assume responsibility for the rock engineering support service as a whole, and for all reports issued by the rock engineering department	Analysis 50% Judgement 50%
12	Prepare and manage an annual departmental budget	Analysis 60% Synthesis 30% Judgement 10%
13	Arrange and direct local and regional technical meetings, seminars, and symposia, and participate actively in voluntary associations	Knowledge 40% Comprehension 40% Judgement 20%

The advanced rock engineering certificate holder should visit the mining operations once or twice a week, or 5 times per month, spending the remaining 18 shifts on surface for management and administration, liaison with line management, mine planning, report writing, design, and analytical activities. Activities 1 to 5 are performed partly in the operations, and partly in the office, with the remainder being performed entirely in the office. Activities 1 to 9 and 11 are performed on an ongoing basis, and are estimated to take up 90%, or 21 shifts of the ARECH's time, while activities 10, 12, and 13 take up the remaining 10%, or 2 shifts per month. Using these estimates to weight the average cognitive levels (assuming that the activities in each group enjoy approximately equal weighting) we find that the average cognitive levels required for the ARECH are 14% knowledge, 9% comprehension, 23% application, 29% analysis, 8% synthesis, and 17% judgement.

This overall result shows that the ARECH relies on application, analysis, and judgement to perform the work, using engineering principles and engineering problem solving methods. Designs tend to be based on previous experience and accepted industry practice, explaining the low level of synthesis. Judgement tends to be relatively high because of the many unknowns and unpredictabilities in rock mechanics, and because of the increased managerial function. The ARECH is in a more senior position, not because of more advanced training, but because this position holds a mine-wide responsibility and rock engineering support service responsibility.

As with the previous two levels, the ARECH is required to be computer-literate, and in addition, have a deeper understanding than his/her subordinates of the numerical models used for analysis and synthesis. The ARECH will also be familiar with statistical analysis, and "what-if" comparative numerical modelling. Finally, the ARECH must demonstrate developed communication, management, and leadership skills.

APPENDIX B
BLOOM'S TAXONOMY OF EDUCATIONAL OBJECTIVES

BLOOM'S TAXONOMY OF EDUCATIONAL OBJECTIVES: COGNITIVE DOMAIN

(After The Oklahoma State Department of Education, 1994)

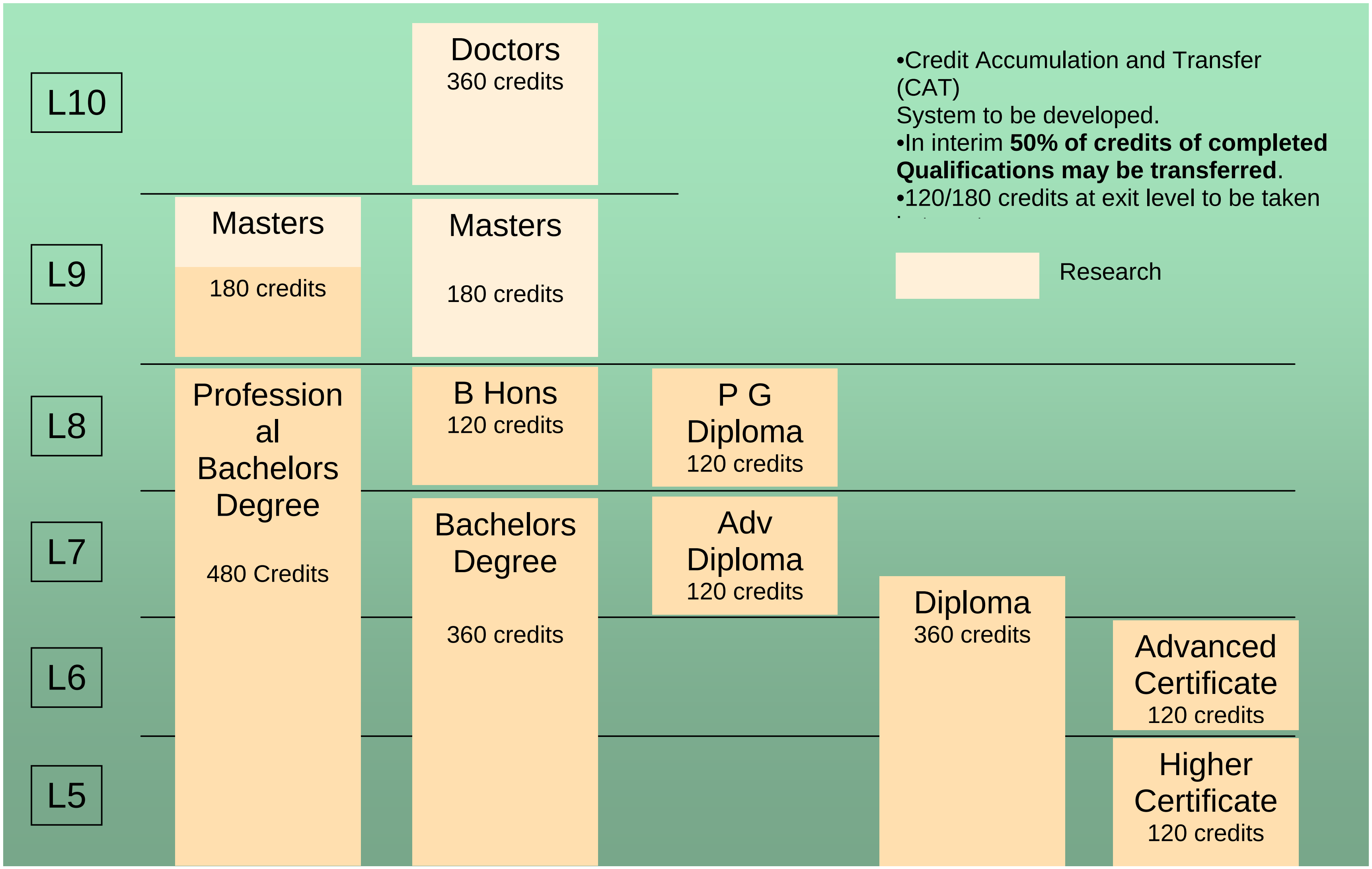
Bloom's Taxonomy of Educational Objectives sets out six cognitive domains, from knowledge at the lowest level to evaluation at the highest level. The domains are here described in terms of using and understanding language, but they can be readily applied to technical fields as well. There is no hard division between domains; instead there is a transition from one to another. Bloom's taxonomy has been in use since 1956, the year it was first introduced. The six cognitive domains are listed below (the italicised small text at the end of each description is an interpretation for engineering, after application by the Faculty of Engineering, University of Pretoria, see also Handley et al., 2001):

1. *Knowledge:* involves rote memory skills; the learner is only required to recall the appropriate information. *The engineering student knows facts, formulae, definitions and descriptions, only at an introductory level.*
2. *Comprehension:* the lowest level of understanding. The learner knows what is being communicated and can make use of this information without seeing its fullest implications. Categories: translation, interpretation, and extrapolation. *The engineering student understands the meaning of the facts, understands the meaning of the symbols in the formulae, and comprehends definitions and descriptions.*
3. *Application:* the ability to use general abstractions in particular and concrete situations. It involves applying the learned principles to the solution of presented problems. *The engineering student is able to apply the facts, formulae, definitions, and descriptions in the solution of simple problems.*
4. *Analysis:* involves the breaking down of a whole communication into its parts and being able to understand the relationship between the parts. This is done in order to clarify and to understand the organization of the communication - an indication of divergent thinking. Categories: analysis of elements, relationships, and organizational principles. *The engineering student is able to solve more complex problems by breaking them down to simpler parts, and then applying the facts, formulae, definitions, and descriptions in the solution of the simplified elements. Numerical modelling and statistical analysis are good examples of engineering analysis.*
5. *Synthesis:* the ability to bring separate parts together to form a whole that did not previously exist - an indication of convergent thinking. Categories: production of a unique communication, production of a plan or proposed set of operations, and derivation of a set of abstract relations. *The engineering student is able to assemble a solution for a pre-specified problem from facts, and analyses, and projections. Compilation of a research report after completing a unique research project provides a good example. An optimised mine design on an established mine (incorporating the conflicting requirements of ventilation, safety, rock mechanics, production constraints, geology, and financial constraints into an integrated whole) is another good example of synthesis.*
6. *Evaluation:* judging the value of materials and methods for given purposes using internal evidence or external criteria. *The engineering student is able to use analysis and synthesis of incomplete data to compile a balanced evaluation of the situation at hand. A bankable feasibility study of a green fields project, or the evaluation by a judge of evidence in a court case to reach a verdict, are good examples of evaluation.*

Table B1: Verbs to Assist in Teaching & Measuring Skills Based on Bloom's Taxonomy of Educational Objectives: Cognitive Domain

Knowledge	**Comprehension**	**Application**	**Analysis**	**Synthesis**	**Evaluation**
Define	Convert	apply	analyze	arrange	assess
Designate	Defend	change	appraise	assemble	choose
Describe	describe	compute	break down	collect	conclude
Enumerate	Discuss	construct	calculate	compose	contrast
Find	Edit	demonstrate	categorize	create	compare
Identify	estimate	employ	compile	derive an approach	critique
Label	Explain	illustrate	contract	design	defend
List	Express	interpret	criticize	devise	evaluate
Match	Extend	manipulate	debate	explain cause	judge
Memorize	extrapolate	modify	diagram	formulate a hypothesis	justify
Name	generalize	operate	examine	generate	oppose
Outline	infer	practice	experiment	modify	revise
Recall	locate	predict	inventory	organize	select
Recite	paraphrase	prepare	reorder	plan	score
Relate	predict	produce	separate	rearrange	summarize
Repeat	report	schedule	subdivide	reorganize	support
Select	restate	show		revise	
State	rewrite	sketch		summarize	
	review	solve		synthesize	
	relate	translate		write	
	summarize	Use			

APPENDIX C
CURRENT HIGHER EDUCATION QUALIFICATIONS FRAMEWORK


L10
L9
L8
L7
L6
L5
Doctors
360 credits
Masters
180 credits
Masters
180 credits
Professional Bachelors Degree
480 Credits
B Hons
120 credits
P G Diploma
120 credits
Bachelors Degree
360 credits
Adv Diploma
120 credits
Diploma
360 credits
Advanced Certificate
120 credits
Higher Certificate
120 credits
•Credit Accumulation and Transfer (CAT)
System to be developed.
•In interim 50% of credits of completed Qualifications may be transferred.
•120/180 credits at exit level to be taken
Research