

‘Educating the Future Mining Engineering Practitioner’

Tuks Mining Engineering: 1961–2011

‘Celebrating 50 years of Excellence in Mining Engineering Education’

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Introduction

The Department of Mining Engineering at the University of Pretoria accepts that the process of teaching and learning improvement is an ongoing exercise with the ultimate aim to deliver well-rounded mining engineering practitioners. Various challenges impact on the success of this process. An integrated and innovative process was developed and is followed in the Department to overcome these challenges. The aim of the Department is to apply a holistic teaching approach by introducing multiple integrated interventions with regards to teaching and learning strategies. Three phases of this process are discussed in this article, and are illustrated in Figure 1.

During the first phase, prior to 1999, several teaching and learning challenges were identified in the Department of Mining Engineering. These challenges are discussed in the next section. In the current phase, a variety of interventions to address the challenges are being developed, implemented (in some cases piloted), and evaluated. The future phases will focus on the improvement, successes, and full roll-out of current interventions, as well as on training, development, and support for all staff members to participate in the process. (Figure 1)

The process of teaching and learning improvement described in this article is based on and supported by the prescribed Engineering Council of South Africa (ECSA) outcomes. These outcomes are also incorporated in the South African Qualifications Authority’s (SAQA) outcomes for the Engineering qualification.

Challenges

The main challenges that the Department faces are:

- *Students specialize only from the third year of study*—The Mining Engineering qualification was restructured prior to 2008. A result of this was that students are now introduced to the mining specialization modules only in the third year of study. It is a challenge to introduce basic mining concepts, and also to progress to appropriately high levels of learning, in the third and fourth years.

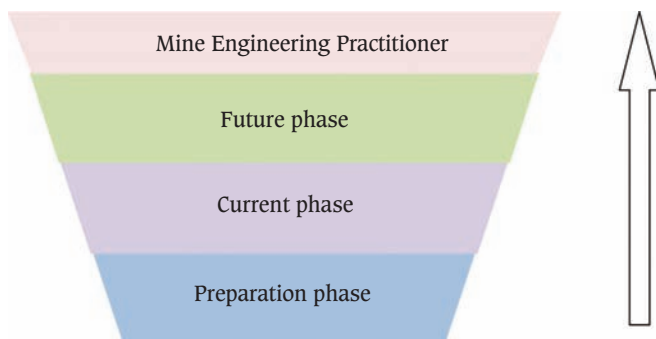


Figure 1—Phases of progression

- *The intangible world of the mining engineer*—The world of a mining engineer is sometimes not as tangible as it is for other engineering disciplines. Students grow up in the ‘visual era’, but are challenged with several mining-related scenarios that do not make sense to them at all.
- *The mining engineer as manager and supervisor*—Management (planning, organizing, and control), which includes supervision and interpersonal skills, as well as teamwork, are very important aspects of the everyday life of a typical mining engineer. The teaching of these aspects is not measurable in the traditional context of the engineering curriculum.
- *Academic standards*—The pass rate requirement of 85% for engineering modules in the faculty of Engineering, Built Environment and Information Technology (EBIT) is aligned to the University of Pretoria’s drive towards improving student success and retention. This should be achieved without the lowering of the standards and neglecting the ECSA outcomes.

These challenges play out practically into five focus areas, which are: content, professional skills, support, communication, and teaching. The most important aspects of each are listed below.

Content

- Due to the fact that most of the mining engineering students have never been on a mine before, either on surface or underground, it was very difficult for them to visualize the concept that the lecturers are trying to explain
- The fact that the new concepts and terminology and the work environment of the mining engineer could not be visualized and explained accordingly had a negative impact on students’ results
- Students specialize in mining engineering from the third year, without any prior knowledge of basic concepts.

Professional skills

- Management and leadership principles, a key area of importance in the outcomes of becoming a good mining engineer, were not addressed as a critical component in the curriculum
- Mining engineering as a people’s profession was not experienced as such by the students. The perception was that the department was strict and impersonal.

Support

- Mentoring and coaching of individuals and teams were not part of the teaching and learning programme. Problem areas were identified too late, to the detriment of the students and disappointment of the lecturer
- The percentage of mining students passing in certain mining and other modules was quite low (some as low as 50%), and the real reason for this had to be identified and rectified.

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Communication

- ▶ The increase in student numbers and the subsequent increase in work-groups created communication problems (multi-language environment and second language tuition)
- ▶ Lecturers traditionally received, relatively speaking, good feedback reports from students, but there was an indication of the need for improvement.

Teaching

- ▶ Class attendance and throughput were poor
- ▶ A different approach was needed to incorporate larger groups in terms of the teaching and learning strategy
- ▶ The multi-language environment created a challenge of its own, as the department changed the tuition language for third- and fourth-year students to English only
- ▶ Higher student numbers also made mine visits more difficult due to logistical challenges associated with these visits
- ▶ When group work was undertaken, selection and management of groups were not carried out according to a formal scientific approach (incorporating management principles)
- ▶ Management and assessment of group work was problematic and not professionally conducted. The reason for the failure/success of groups and/or students could also not be 'measured' effectively through conventional assessment strategies.

The Department embarked on a process to prove that a holistic multi-intervention approach to improving teaching and learning was in fact possible and sustainable through optimization of the teaching and learning experience. If the answers to the challenges mentioned above were known, it would be feasible to develop the 'ideal' mining engineering student and subsequently a quality mining engineering practitioner.

Interventions

The innovative development process of the qualification links to the five focus areas discussed in the previous section is illustrated in Figure 2. The focus areas can be represented as arrows, to indicate the growth and progression of the intervention process.

Content

An instructional designer (sponsored annually by the South African Collieries Managers' Association) was employed by the Department to design all mining modules in a format where the one-dimensional script would be enhanced through the inclusion of

- ▶ High quality pictures and illustrations
- ▶ Simulations of complex mining sequences that previously

were not possible to comprehend without underground visits (and even then were difficult to comprehend)

- ▶ Animations showing difficult concepts in mining, which also included 'mouse-overs' to make explanations of mining sketches and descriptions more understandable for the inexperienced mining student
- ▶ Video material to make 'dead' images 'alive'.

A databank of mining industry videos has been built up as part-time viewing material for students to enhance their understanding of difficult mining concepts and procedures, including reconstructions of typical mine incidents and accidents with three-dimensional animations (for example, incident reconstruction simulations (IRSs) and geological features from a company Simulated Training Solutions (STS). These videos and simulations have been introduced to some modules already, and will further enhance students' comprehension of aspects previously only possible through on-mine visits. The videos can also be used to introduce students to the basic mining concepts.

Professional skills

Several selection procedures were used to identify differences in the personalities and group tendency relationships of individuals. In previous years, mine design groups were made up by using the Myers Briggs tool, DISC analysis (Dominance, Influence, Compliance, and Steadiness), as well as gender, race, and the commodity type from which a student had a bursary (coal mining, gold mining, platinum etc).

A new approach to identifying a specific student's thinking preference, the Herman Brain Dominance Instrument (HBDI) tool (whole brain analysis) was introduced to identify the thinking preference of each of the students in the final year mining engineering class. The following illustration depicts the different aspects of thinking preferences as identified through HBDI and the plot summary of the 2010 final year mining engineering students (most of the class is grouped in the blue (engineering) quadrant). Lecturers also changed to a process of adapting teaching strategies according to the HBDI approach. (Figures 3 and 4.)

The Shadowmatch tool, for determining dominant habits within an individual, was also included as a way of distinguishing individuals from each other. The habits identified with this tool were compared to habits associated with successful mining engineers and were found to be very favourable. This information can also be utilized in student personal professional development.

Both the HBDI and Shadowmatch tools were sponsored by the Department of Mining Engineering through funds secured from short courses in the Safety Risk Management Process (SRMP) presented to Anglo American. In this way the Department is investing in the future of quality mining engineers without putting a further financial burden on the students themselves or the companies sponsoring bursaries.

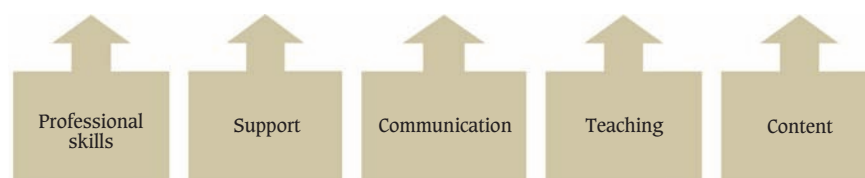


Figure 2—Five focus areas in developing 'ideal' mining engineering practitioners

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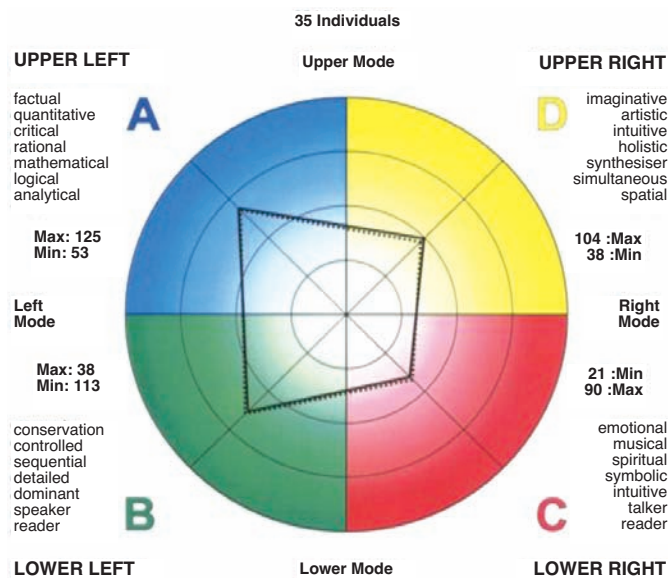


Figure 3—HBDI whole brain explanation

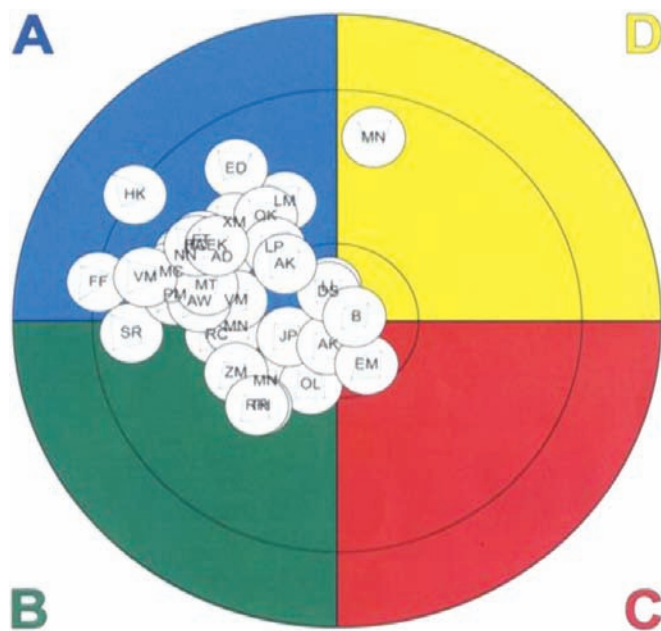


Figure 4—HBDI whole brain Mining Engineering students group plot

The latest intervention that has been included in the Department is the measuring of the emotional intelligence (EQ) level of all our final-year students. The purpose of this exercise is to allow students to understand more about themselves and in this way find out more about various aspects pertaining to emotional intelligence, and in what way this understanding can enhance their ability to deal with difficult emotional situations in their careers. As part of this intervention, students approach the Department for support and help in this regard. We have also introduced the availability of a Personal Development Programme (PDP) for use by our final-year students, which has been very well received. It is further envisaged that in future the PDP will be carried out for all our mining engineering students.

Mentoring and coaching to develop leadership skills were also introduced for the first time in 2009 with the mine design groups. Group discussions and gatherings at pre-arranged appointment times led to very important lessons being learned. These included group dynamics, mannerisms, and responses to questions under pressure, as well as developing listening and talking skills by all individuals in the group. These sessions were videotaped and played back to the participants to show what their responses were to certain activities in the group sessions. This process will be continued and further developed in the future.

As part of an assessment procedure, the development of each group was monitored and discussed on an ongoing basis, identifying specific needs pro-actively. This process amplified the

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relevance of continuous monitoring and assessment of progress of the groups and individuals within the groups as part of an ongoing improvement strategy.

On an annual basis the mine design teams now spend a mentorship and coaching weekend in preparation for their mine design project in the second semester. These weekends are also sponsored by the contribution of bursary companies as well as private donations and have become a very important activity in the department.

Support

- ▶ The 'caring nature' (addition to a sound technical knowledge base) of the mining engineering practitioner is developed amongst lecturers and students (soft skills). The message is also created that the upholding of a high standard is not negative, but preparation for the mining industry
- ▶ Academic support is provided to students in non-compulsory forum information sessions to prepare them for the qualification during first and second years
- ▶ Personal lifeskill development programmes, mentoring, and peer support in collaborative learning sessions are being developed and implemented (soft skills)
- ▶ Support in exposure to material relating to professional certificates is provided through practical videos (for example, on blasting, ventilation, geology etc.) donated by industry (93 Degrees and Virtual Training Television (VTTV)). The support of these companies is greatly appreciated
- ▶ The Department has its own computer laboratory, made possible through generous support by the METF and the Dean, Professor Roelf Sandenbergh, as well as other industry contributions. This now enables students to explore the additional learning material in the secure environment of the Mining Engineering Department
- ▶ Simulated Training Solutions (STS), a Pretoria-based safety simulation company, has also collaborated with the Department of Mining Engineering in making simulation material available

Communication

- ▶ All announcements are communicated to students via the University learning management system (ClickUP).
- ▶ A large LCD television screen at the entrance to the Department (Figure 5) displays important notices, as well as other newsworthy mining information, on a continuous basis. This is updated weekly to keep the information current.
- ▶ The bulk SMS system introduced by the Department of Mining Engineering is successfully used to communicate with students on an ongoing basis when necessary.

Teaching

- ▶ The selection tools for group work are used to improve the efficiency and productivity of groups. Groups made up in this way were much more productive and more efficient than those selected with the haphazard approach previously used
- ▶ Group work discussions and sharing of ideas of how problems on mines can be solved lead to interactive and high-level discussions and participation with group work

implemented according to professional group work principles

- ▶ All the mine design groups attend a weekend in-depth team coaching session where the different aspects pertaining to group work, including mentorship and coaching, are discussed and dealt with in detail
- ▶ As part of a strategy to make group discussions more feasible, the mining laboratory area, which was not being used effectively, was converted into discussion rooms for group work activities incorporating mentoring and coaching sessions to develop leadership skills (Figure 6)
- ▶ A radio-based Inter-write Personal Response System (PRS), which allows lecturer/student interaction by means of 'clickers', was introduced in 2010 (Figure 7) where pre-designed critical concept questions are set as part of a powerpoint presentation to the students. When all students have answered a question, the lecturer receives immediate feedback in the form of a histogram displayed on his/her computer. In this way shortcomings are much sooner identified on key principles embedded within the outcomes for the module at hand.
- ▶ Lecture material for the instructionally designed completed modules is made available on CD to the students at the beginning of the semester. This enhances the knowledge and understanding component of learning for the student, with the lecturer then spending more time on the



Figure 5—The new-look Mining Engineering Department



Figure 6—New Department of Mining discussion rooms

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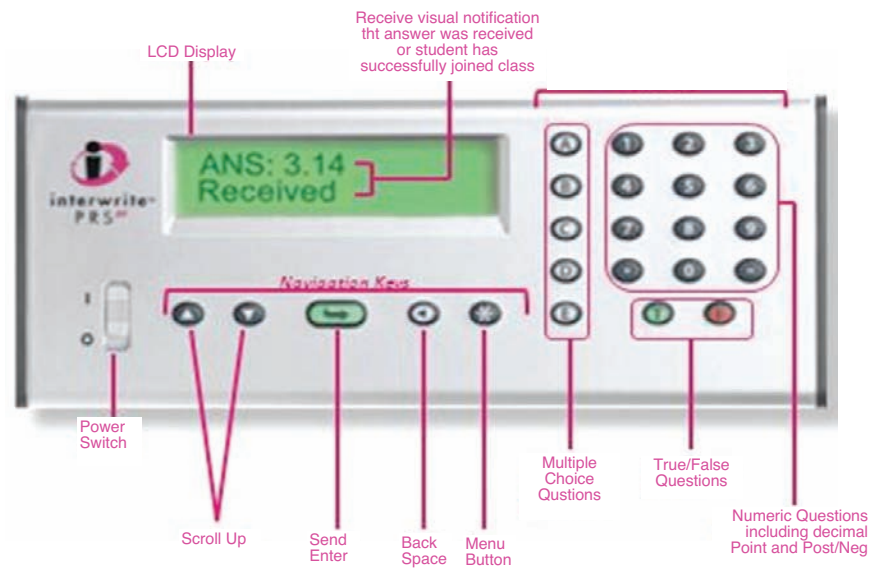


Figure 7—The 'clicker'

'application and design' component of teaching. It is envisaged that all mining modules will be instructionally designed by the middle of 2012

- A system of unannounced class tests has been partly introduced, which resulted in better preparedness and improved class attendance.

By employing this holistic approach, key elements of the teaching and learning strategy could be monitored on a group and individual basis, making the learning experience much more rewarding and worthwhile for the lecturers and students alike.

Impact on teaching and learning

The interventions have had several impacts. These impacts are also strengthened by other interventions, such as strict subject prerequisite.

- In the June 2011 examinations, there was a large increase in the number of students that passed the 4th year modules compared to 2010. It is speculated that the implementation of a holistic approach of interventions has had an impact on the students and their results alike (this will be monitored continuously)
- The pass rate as a percentage of the number of students for all the mining courses has increased significantly (Table I)
- Students 'reflect' on their academic experience in writing to the various lecturers, and this creates an environment of trust. Students get feedback on these reflections as part of a Department commitment to offering a professional service of excellence
- Student engagement, as well as preparedness for class, class attendance, and class participation has improved significantly
- The average score for feedback from students for the lecturers in the Department as a whole has also increased significantly compared with previous years
- This process of improvement is sustainable, as it is supported by the HOD and lecturers in the Department.

The new holistic interactive multimedia, as well as the group dynamic approach, was presented to the mining alumni and mining advisory board in industry and was very well received. It was complimented by Mr Wilco Uys, the chairman of the Minerals Education Trust Fund.

Summary

Figure 8 illustrates and summarizes the teaching and learning development process discussed in this article.

The five main focus areas

The innovative development process of the qualification consists of the five focus areas as defined and discussed earlier. Each of these is represented as an arrow (shown in the Figure 8), to indicate growth and progression. Each arrow is increasing in size in each phase in a vertical direction to demonstrate how the specific focus area is developing and how more supportive elements are built into the process. The arrows in each band are also moving closer together (horizontally), to illustrate how elements eventually will be integrated into a holistic learning experience for all students in all modules.

Developmental phases

Three phases of development of the intervention, namely the preparation, current, and future phases, are represented as three bands of the trapezium in Figure 8. Each phase leads to a broader base on which the next phase can be built. The development

Table I

Pass rate of all students for all mining courses

Module code	2009	2010
PEE 410	50%	93%
PMY 410	60%	90%
PSZ 410	80%	88%

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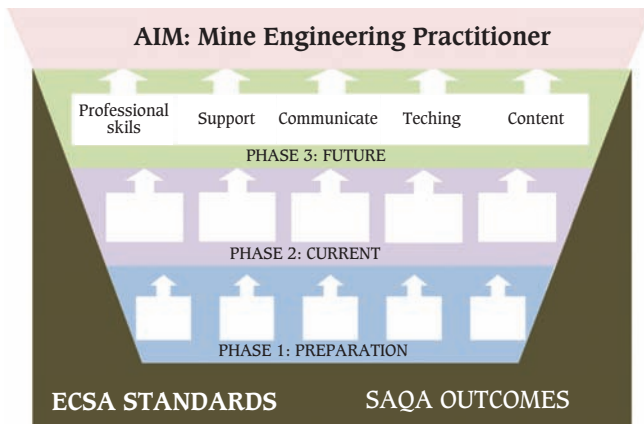


Figure 8—The development process of innovative teaching and learning for the mining engineering qualification

process is one of continuous planning, acting and reflecting. Each new intervention is planned with care, implemented, and then reflected on by academic staff, support staff, and industry as well as the students. The results of these reflections are utilized to improve the interventions, or to plan new interventions where necessary.

Phase 1: Preparation

Outdated ways of teaching and learning and the make-up of the new-millennium students forced lecturers to start thinking more innovatively and incorporating some key concepts such as visualization of lecture material. Several challenges (as discussed) as well as potential interventions to improve the situation were identified during this phase. Professor Roger Thompson started doing some real groundwork with regards to instructional designing of his surface mining module, but it was only after he left the University in 2008 that a conscious decision was made to incorporate instructional design for all modules, based on the positive reaction from students as well as industry practitioners.

With the shortage of staff experienced in 2009 the implementation of the process was delayed temporarily. The employment of three new staff members at the end of 2009 changed this, and new targets for instructional designing of other mining modules, as well as the incorporation of the other aspects, were decided upon. In the meantime the group discussion rooms were built and negotiations to obtain industry simulations, animations, and video material were under way.

Phase 2: Current

Elements that have been developed and implemented over the last two years include the use of instructionally designed material, continuation of instructional development of other material, staff development in and application of student-centred teaching strategies, as well as a new look and feel to the department. All of these add a flavour of professionalism and a sense of belonging, and have had a major impact on the

perception of mining by the students in the department. Plans for improvement are revisited and re-engineered continuously.

Phase 3: Future

Elements are implemented in more modules, and staff members are adapting to and being trained/educated in the new paradigm. Elements are also integrated into a holistic process of teaching and learning.

The development process is therefore depicted as an ever-growing trapezium to indicate the importance of constant renewal and reflection. This, combined with the collective buy-in of all staff members into the process, ensures the sustainability, not only of the process of development and growth, but also of the implementation of interventions.

Aim: Mine Engineering Practitioners—The aim of the intervention is to develop well-rounded Mine Engineering Practitioners who are prepared for the many challenges of their future workplaces, through a combination of innovative teaching and learning elements.

Context: ECSA Standards / SAQA Outcomes—This process, as well as the mining engineering qualification, is based on and supported by the prescribed ECSA/SAQA outcomes. The department is also accredited with ECSA.

Extending the context—The model illustrated in Figure 8 can also be applied to the development process of a young mining engineering student from first year until graduation and completion of the professional engineering qualification (including the practical part of the programme). As the five components (content, professional skills, support, communication, and teaching and learning) develop in stature and size (represented upwards and sideways), the student also gains maturity and experience in the mining industry.

Conclusion

There has never been a more in-depth critical evaluation of the teaching and learning strategy of the Department of Mining Engineering to improve mining engineering education than in the last few years. Issues such as integration, diversity, gender changes, literacy and language issues, as well as quality of education in the South African school system, made it obvious that a different approach to teaching and learning had to be adopted. It was also realized that due to the complexities and specialities associated with mining engineering as a career, a number of different approaches have to be integrated into a holistic approach to mining education.

The results obtained thus far from all the different aspects that comprise this holistic approach show a positive contribution to the attitudes of the students and lecturers alike. The cognitive level of engagement of the students has increased considerably, and their perception and attitude towards lecturers has changed.

Through the visits from the Mining Advisory Board as well as the Minerals Education Trust Fund (METF), the Department received many compliments and recognition for this very bold step of introducing several innovative teaching and learning strategies into a holistic teaching and learning approach. For this effort and contribution, the Department of Mining Engineering was awarded a Laureate for Education Innovation by the University of Pretoria in October 2010. ♦