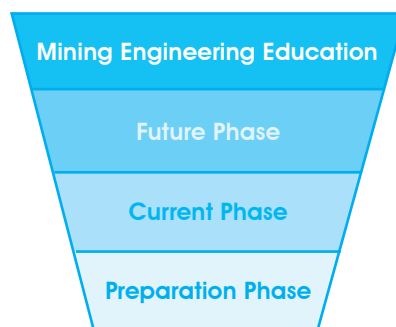


Real-time mining engineering education for real-time mining engineers

by Prof Ronny Webber-Youngman and Dr Ronel Callaghan

The Department of Mining Engineering accepts that the process of improving teaching and learning is an ongoing exercise with the ultimate aim of delivering well-rounded mining engineering practitioners. Thus, an integrated and innovative process was developed and followed in the department in order to apply holistic teaching approaches and principles. The process includes the introduction of multiple integrated interventions regarding teaching and learning strategies.

This process entailed three phases. Prior to 1999 (Preparation Phase), several teaching and learning challenges were identified. Since then (Current Phase), various interventions have been developed, implemented (and in some cases piloted) and evaluated to address the challenges. The Future Phase will focus on improvement, successes and the full roll-out of current interventions, as well as on training, development and support for all staff members to participate in the process.



→ 1. Phases of progression.

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

The department faces the following main challenges:

- Following the restructuring of the mining engineering qualification prior to 2008, students only specialise in mining engineering from their third year of study. The introduction of basic mining concepts is therefore a challenge, as is progressing to the appropriate high levels of learning in the third and fourth years of study.

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

Focus areas

These challenges played out practically in five focus areas: content, professional skills, support, communication and teaching.

- **Content:** Because most mining engineering students had never been to a mine (on the surface or underground), it was very difficult for lecturers to make them “see” what they were trying to explain. New concepts and terminology and the work environment of the mining engineer could not be visualised and explained and therefore had a negative impact on students’ results. Students specialised in mining engineering from their third year of study without any prior knowledge of the basic concepts.

- **Professional skills:** Management and leadership principles, which are of key 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 created that the department was strict and impersonal.
- **Support:** The mentoring and coaching of individuals and teams was not part of the teaching and learning programme. Problem areas were identified too late, to the detriment of the student and the disappointment of the lecturer. The percentage of mining students that did not pass in certain mining and other modules was quite high (in some modules the failure rate was as high as 50%). The real reason for this had to be identified and rectified.
- **Communication:** The increase in student numbers and subsequent increase in work groups created communication problems (particularly in a multilingual environment and given the realities of students who receive tuition in their second language). Relatively speaking, lecturers had traditionally obtained good feedback reports from students, but a need for improvement was indicated.
- **Teaching:** Class attendance and throughput was poor. A different approach was needed to incorporate larger groups in terms of the teaching and learning strategy. The higher student numbers also made mine visits more difficult due to the logistical challenges associated with these visits. When group work was utilised, the selection and management of groups was not done according to a formal, scientific approach

that incorporated management principles. The management and assessment of group work were problematic and were not done professionally. The reason for the failure or 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 the optimisation of the teaching and learning experience. If the answers to the abovementioned challenges were found, 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 above. In Figure 2, the focus areas can be represented as arrows to indicate the growth and progression of the intervention process.

Content

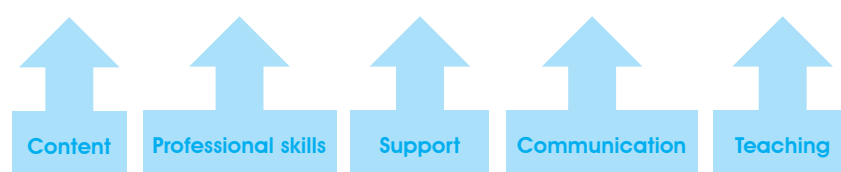
The department employed an instructional designer (sponsored annually by the South African Collieries Managers' Association) to design all mining modules in a format where a one-dimensional script would be enhanced through the inclusion of high-quality pictures and

illustrations, simulations of complex mining sequences that had previously not been possible to comprehend without underground visits (and even then they 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 to the inexperienced mining student, and video material to make "dead" picture images come alive.

A databank of mining industry videos was obtained as part-time viewing material for students to enhance their understanding of difficult mining concepts and procedures. These included reconstructions of typical mine incidents and accidents with 3D animations, for example, accident reconstruction simulations (ARs) and geological features. These videos have already been introduced in some modules and will further enhance students' comprehension of aspects that had previously only been experienced through on-mine visits. The videos can also be used to introduce students to basic mining concepts.

Professional skills

Several selection procedures were used to identify differences in the personalities and group tendency relationship make-up of individuals. In 2009, the mine design groups were composed using the Myers-Briggs tool, DISC (dominance, influence, steadiness and compliance) analysis, and according



→ 2. Five focus areas in developing "ideal" mining engineering practitioners.

to gender, race and the commodity type from which a student had a bursary (coal mining, gold mining, platinum, etc).

In 2010, as part of a new approach of 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. Figure 3 and

Figure 4 depict the different aspects of thinking preferences as identified through HBDI and illustrate the plot summary of the 2010 final-year mining engineering students. Most of the class was grouped in the blue (engineering) quadrant. Their lecturers are also in the process of adapting teaching strategies according to the HBDI approach.

The Shadowmatch tool, which determines dominant habits in an individual, was introduced for the

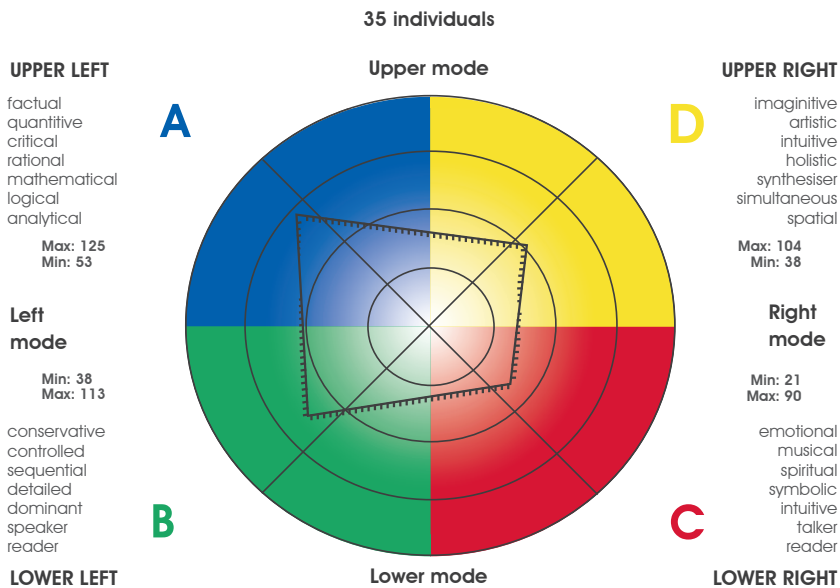
first time in 2010 and will also be included as a way of distinguishing individuals from each other. The habits identified with this tool can be compared to the habits associated with successful mining engineers. This information can also be utilised in future for students' professional development.

Both these tools were sponsored by the Department of Mining Engineering through funds secured from short courses in the safety risk management process (SRMP) that were presented to Anglo-American. The department is investing in the future of quality mining engineers without putting a further financial burden on the students and/or bursary companies.

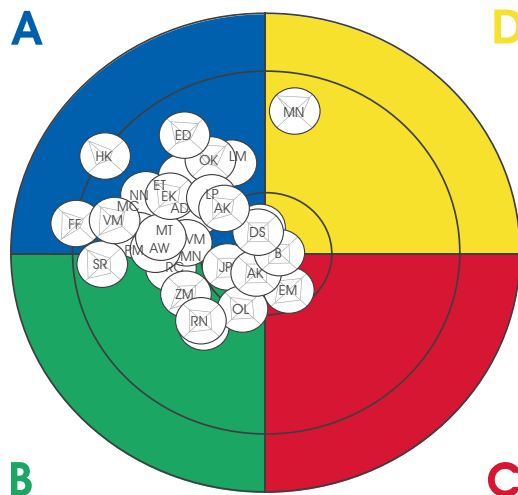
Mentoring and coaching were introduced for the first time in 2009 to develop leadership skills in the mine design groups. Group discussions and gatherings on pre-arranged appointment times led to very important lessons learned.

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 video-taped and played back to the participants to show their responses 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 proactively. This process amplified the relevance of the continuous monitoring and assessment of the progress of groups and individuals in the groups as part of an improvement strategy, motivated as an ongoing process.



→ 3. HBDI whole-brain explanation.



→ 4. HBDI whole-brain mining engineering students group plot.



→ *The implementation of a holistic approach of interventions could have an impact on students' results.*

Support

The “caring nature” (soft skills) of the mining engineering practitioner (as an addition to a sound technical knowledge base) is developed in lecturers and students. The message is also conveyed that upholding a high standard is not negative, but serves as preparation for the mining industry. Academic support is provided to students in non-compulsory forum information sessions during their first and second years of study to prepare them for their qualification. Personal life skills development programmes, mentoring and peer support (soft skills) are being developed and implemented in collaborative learning sessions.

Support is provided through exposure to material relating to professional certificates by means of the utilisation of practical videos that are made available by the industry and financed by the department (for example, videos on blasting, ventilation and geology). The department acquired its own computer laboratory in the second semester of 2010. This will enable students to explore additional learning material in the secure environment of the Department of Mining Engineering.

Communication

All announcements are communicated to students via the University’s learning management system (ClickUP). A big LCD monitor at the entrance to the department also depicts 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 that was introduced by the Department of Mining Engineering is successfully used to communicate with students on an ongoing basis.

Teaching

The selection tools for group work are used to improve the efficiency and productivity of groups. It is envisaged that groups made up in this way will be much more efficient and productive than groups composed according to the haphazard approach previously used. Group work discussions and the sharing of ideas on how problems on mines can be solved lead to interactive and high-level discussions and participation where group work is implemented according to professional group work principles.

All the mine design groups attend a weekend session of in-depth team coaching 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 had not been used effectively, was converted into discussion rooms for group work activities (incorporating mentoring and coaching sessions to develop leadership skills).

A radio-based Interwrite personal response system (PRS) that allows lecturer and student interaction (clickers), was introduced in 2010. Pre-designed critical concept questions are set as part of a PowerPoint presentation. Once all the students have answered the set question, the lecturer receives immediate feedback in the form of a histogram displayed on his or her computer. In this way, shortcomings on key principles that are embedded in the outcomes for the module at hand are identified much sooner.

Lecture material for the instructionally completed modules is made available on CD at the beginning of the semester, enhancing the knowledge and understanding component of learning for the student, with the lecturer then spending more time on the application and design component of teaching. A system of unannounced class tests has also been partly introduced, which has resulted in better preparedness and improved class attendance. By employing this holistic approach, key elements of the teaching and learning strategy can be monitored on a group and individual basis and has made the learning experience much more rewarding and worthwhile for lecturers and students alike.

Impact on teaching and learning

The interventions that have been implemented thus far have had several impacts. These impacts are strengthened by other interventions, such as strict subject prerequisites. Since the examination in June 2010, there has been a large increase in

the number of students that have passed the fourth-year modules in comparison with the previous year. It is speculated that the implementation of a holistic approach of interventions could also have had an impact on students and their results. This will be monitored on an ongoing basis. The pass rate, as a percentage of the number of students enrolled in all the mining courses, has increased significantly, as is indicated in Table 1.

Table 1. Performance of students in certain modules in 2010 in comparison to 2009

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

In a workshop conducted for third-year mining engineering students during 2009, the reasons for their poor results were discussed. Several personal problems and other areas of concern were identified. This information and will be used on an ongoing basis in future in the development and improvement process. Student engagement, as well as preparedness for class, class attendance and class participation, has improved significantly. The average score in terms of student feedback on the lecturers in the department as a whole has also increased significantly from that of previous years. This process of improvement is sustainable, as it is supported by the head of department and lecturers in the department.

The new holistic interactive multimedia, as well as the group dynamic approach, was presented to the alumni of the Department of Mining Engineering and the Mining Advisory Board in industry and was very well received. It was also

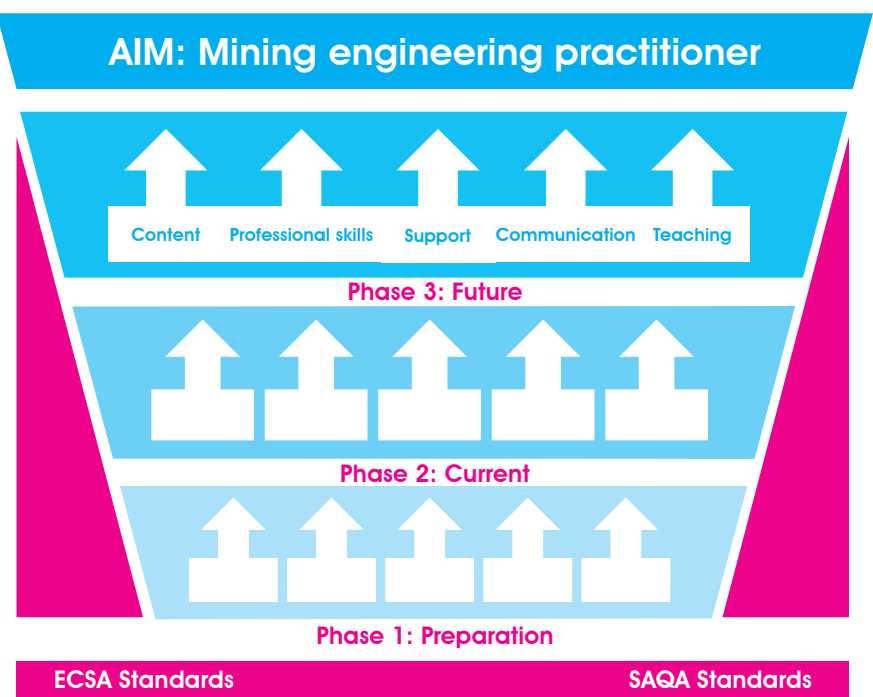
complimented by the chairperson of the Minerals Education Trust Fund. Figure 5 illustrates and summarises the teaching and learning development process implemented in the Department of Mining Engineering.

The five main focus areas

The five focus areas that comprise the innovative development process of the qualification are each represented as an arrow to indicate growth and progression. Each arrow increases 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 also move closer horizontally to illustrate how elements will eventually be integrated into a holistic learning experience for all students in all modules.

The aim of the intervention is to develop well-rounded mining engineering practitioners who are prepared for the many challenges of their future workplaces through a combination of innovative teaching and learning elements. This process, as well as the mining engineering qualification, is based on and supported by the prescribed outcomes of ECSA and SAQA. The department is also accredited with ECSA.

The figure can also be applied to the development process of a young mining engineering student from his or her first year until he or she has graduated and completed his professional engineering qualification (including the practical part of the programme). As the five components develop in stature (represented upwards and sideways), the student also gains maturity and experience in the mining industry.



→ 5. The development process of innovative teaching and learning for the mining engineering qualification.

Developmental phases

The three phases of development are represented as bands on a trapezium. Each phase leads to a broader base on which the next phase can be built. Development entails continuous planning, acting and reflecting. Each new intervention is planned with care, and implemented and reflected on by academic staff, support staff, industry and students. The results are utilised to improve the intervention, or to plan new interventions.

Phase 1: Preparation Phase: Out-dated ways of teaching and learning have forced lecturers to think more innovatively about incorporating

concepts such as the visualisation of lecture material. Several challenges and potential interventions to improve the situation were identified.

Phase 2: Current Phase: The elements that are being developed and implemented include the use of instructionally designed material, the instructional development of other material, and staff development in and the application of student-centred teaching strategies. This adds a flavour of professionalism and a sense of belonging, and has a major impact on the perception of mining. Plans for improvement are continuously revisited and re-engineered.

Phase 3: Future Phase: Elements are implemented in more modules and staff members are adopting and being trained or 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.

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, change in the gender composition, literacy and language issues, as well as the quality of education associated with the school system in South Africa, made it clear that a different approach to teaching and learning had to be adopted.

It was also realised that, due to the complexities and specialities associated with mining engineering as a career, various approaches have to be integrated into a holistic approach to mining education. This gave birth to the concept of “real-time mining engineering education for real-time mining engineers”. The provisional results from the different aspects that comprise this holistic approach made a positive contribution to the attitudes of the students and lecturers alike. The cognitive level of engagement of students increased considerably and their perception and attitude towards lecturers also changed.

Through the visits by the Mining Advisory Board and the Minerals Education Trust Fund, the Department of Mining Engineering has received several compliments and recognition for this very bold step of introducing a number of innovative teaching and learning strategies to a holistic teaching and learning approach. ➔

Acknowledgements

The Department of Mining Engineering received a Laureate Award at the biannual Education Innovation Awards. This was in recognition of the process on which it has embarked to improve teaching and learning, and to educate

the future mining engineering practitioner. This award recognises innovative developments that have resulted in improvements in the quality of the student learning experience or environment. Expected standard of good teaching practice should convincingly be exceeded and evidence of sustainability, positive impact and acceptance should be provided in the form of student feedback or appraisal by peers. Nominations for this award are assessed on evidence provided in relation to clarity of purpose with systematic planning, implementation and evaluation, as well as the impact innovation has on the practice of learning and teaching.



➔ *Dr Ronel Callaghan, Education Innovation consultant for the School of Engineering (left), and Prof Ronny Webber-Youngman, Head of the Department of Mining Engineering.*