A national curriculum in Australian minerals education: New generation flexible-delivery undergraduate courses

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A new minerals engineering education programme is being developed in Australia which aims to provide tertiary institutions with a package of educationally sound, high quality courses for undergraduates, postgraduates and professionals. The programme is jointly funded by the Minerals Council of Australia (MCA) and the Department of Education Training and Youth Affairs (DETYA) and brings together academics from a number of leading Australian universities, each developing modules in their particular area of expertise.

The University of Queensland (UQ) and the Julius Kruttschnitt Minerals Research Centre (JKMRC) are jointly responsible for modules in several areas including comminution, physical separation and circuit design and optimization. Other modules are being developed by the University of South Australia (with the Sir Ian Wark Centre), Curtin University and Murdoch University.

The major challenge of the programme is to provide a high standard of education that is accessible to students who may be located at several different institutions and some of whom may be a long distance from the primary course leader. Rather than taking existing course material and putting it 'on the web', the programme aims to improve on past teaching practice through creative pedagogy and the development of interactive multimedia learning resources. Communications technology is used in an unobtrusive way, and the World Wide Web is used to create a flexible, user-friendly learning environment rather than to facilitate delivery of content.

This paper describes the instructional design template currently being used and results of early implementation trials with groups of local and remote students.

Introduction

The past decade has seen numerous calls for reform in minerals industry education. Employer groups and accreditation providers are recommending substantial changes to organization of schools and to pedagogical approach.

A major report was commissioned by the Minerals Council of Australia in 1998 to specifically address the provision of professional training to the Minerals Industry. This report was aptly titled 'Back from the Brink', and has become a landmark document in the Australian minerals education sector. Besides identifying problems with the narrow focus of traditional engineering programmes, the report identifies some major organizational problems amongst the education providers. 'The quality of minerals education in Australia is being undermined by the combined effects of a fragmented system, government funding framework and salary disparities. Changes in higher education are threatening the stability of the system to the point that current minerals-specific education could become a thing of the past.' (The Minerals Council of Australia. National Tertiary Education Taskforce, 1998).

In many ways this reflects a more general view in the engineering sector, where a need has been identified for broadening the curriculum beyond the traditional technology base. The Accreditation Board for Engineering and Technology in the USA (ABET, 2000) now include the following in the list of attributes that engineering programmes must aim to develop in their graduates: an ability to function in multi-disciplinary teams, communicate effectively, understand the impact of engineering solutions in a global and societal context, recognize the need for, and be able to engage in life-long learning, and know about contemporary issues. Accreditation providers in Australia are echoing these sentiments.

The solution proposed to this perceived shortfall in the 'Back from the Brink' report would be at the very least controversial, if not unworkable, in any other field other than mining and minerals engineering. The industry is characterized by a small number of large and relatively powerful employers who have a history of close association with Australian schools in mining, metallurgy and earth sciences. The primary recommendation was for extensive restructuring of the existing education system and for the mining industry to 'take the lead in this restructuring and go on to become an active partner with universities and government in the new system'. The challenge identified by the report's authors was that 'Australia has the potential to be the world's leader in minerals education'.

This recommendation was accepted by the Minerals Council, and a joint funding arrangement put together by the Minerals Council of Australia (MCA) and the Department of Education Training and Youth Affairs (DETYA). Under this arrangement the Minerals Industry Tertiary Education Council (MTEC) was established to
oversee and implement the reform process, with the stated aim of making available ‘the best undergraduate and professional development education for those who pursue careers in the industry’ (Tuckwell, 2002). MTEC is now the driving force behind the development of university collaboration and university-industry partnerships in education.

Development of the MTEC programme

The ‘Back from the Brink’ report concluded that no single Australian educational institution was in a position to meet all the training requirements of industry. Rather than recommending organization of a single high-quality school, the report recommended building on the existing schools to develop a select network of centres which would collaborate to offer ‘a world class minerals program and be able to deliver innovative coursework’.

Funds have been set aside for development of a national programme in each of the disciplines of Mining Engineering, Minerals Process Engineering and Earth Sciences (primarily Mining Geology). Several universities are involved in this programme, and the University of Queensland is a member of both the Mining and the Minerals Process Engineering groups.

In order to foster the collegiate spirit of the various academics in the group, 2-day workshops are held at 6-monthly intervals where members come together to discuss development and implementation issues. General guidelines have been set for programme development, but the delivery mechanism for course material has not been specified. Several implementation models are currently being trialled by the various member groups, including the model discussed in this paper.

Within the Minerals Engineering stream, a schedule of course content was developed and divided between the four members according to their areas of expertise. The members are the University of Queensland (along with the minerals research centre the JKMRC), the University of South Australia (with the Sir Ian Wark Ccentre), Curtin University and Murdoch University. Development of course modules based on this schedule is now well under way, and a number of trials are being run using the material as it becomes available. However, a national integrated delivery programme has not yet been produced.

The UQ approach

The view held at The University of Queensland is that new courses developed as part of the MTEC programme should not only draw on the best available technical content but also break new ground in educational design and delivery. Pedagogical design of our learning material is receiving as much attention as the technical content. Like many of the other institutions in the MTEC consortium, we are working closely with our in-house learning resource and multimedia development units in order to achieve this outcome.

A number of authors have written on how to design good remote-access courses. Bates (1995) looks at all available technologies, old and new, in terms of access, costs, teaching and learning, interactivity and user-friendliness, organizational issues, novelty, and speed. All technologies are discussed in terms of the potential teaching/learning outcomes. Bates suggests that the strength of the WWW is its ability to foster student-student and student-instructor interaction, not its ability to transmit a one-way flow of data. In a later publication Bates (2000) refers to the practice of dumping loads of instructional material onto a website and calling this on-line course delivery as ‘monomedia mania’.

Conversely, the University of Queensland sees the Web as providing opportunities for collaborative learning, allowing students more flexibility in when and how often they access the range of learning resources; and more interaction with each other, the learning material and their teachers. Throughout all of the learning resources and delivery media, students are encouraged to take a more active, searching and questioning approach to their learning. This is achieved through the provision of a wide range of educational multimedia which present case-based scenarios and allow learners to build on ideas and concepts and see the relationship between them.

A number of other initiatives are also taking place in our existing curriculum, including integration of new ‘softer’ material into the technical programme to broaden student perspectives. Some areas we are currently addressing include risk analysis, safety, social impact assessment and training in teamwork and management skills. We also have several students involved in site-based learning opportunities (Beamish et al. 2001), and an expanded programme of field trips and site visits to assist students with putting their learning into context. Although many programmes are very much in the development phase, we envisage that many of these strategies can be integrated into the national MTEC program.

The University of Queensland is constantly upgrading their WebCT license. Among the many advantages of the latest iteration of WebCT, the new version has an improved interface and allows ‘Designers’ (lecturers) to see the students’ view easily. WebCT’s operational elements that drive the platform are written in PERL—but the elements with which the lecturers are required to interact are presented in simple menu-driven interface.

Pedagogical and multimedia design aims

A primary aim in developing these course modules is to improve on past teaching practice, while still maintaining the high technical standard of the traditional curriculum. Selection of an appropriate student-centred learning environment is critical, in accordance with Shuell’s assertion that ‘what the student does is actually more important in determining what is learned than what the teacher does’, (Shuell 1986). The challenge was to achieve a stimulating and engaging environment for all students, including those on campus at University of Queensland, on campus at other institutions and students who might be located in remote mine sites.

Oliver, Omari and Ring (1998) suggest a framework categorizing different components of flexible delivery courses in terms of levels of student engagement and potential learning outcome, with an emphasis on learner activity. There are several available models of good flexible delivery courses that follow these guidelines, including local examples at the University of Queensland. Others include the Canadian Commonwealth of Learning (COL) guidelines (1997) and two American models, the Web-based Education Commission (Office of Post-secondary Education, 2000) and the Pew Learning and Technology program (Twigg, 2000). A common theme of these publications is that good pedagogical design principles are independent of delivery mode and student-teacher interaction and student activity is central to good learning outcomes.
Material, often in the form of Shockwave video and audio is used to present learning tasks. Technologies such as Flash, Shockwave and Java applets provide a range of options for interactivity. These technologies are used to develop virtual environments in which learning and assessment tasks are set. Learners can engage with authentic tasks set in real-world contexts in a structured and sequenced fashion. They are always accompanied by some form of consolidation and rehearsal activity for which students get immediate feedback for both their correct and incorrect answers.

These types of materials, which are currently being developed for the MTEC program, are suitable for both online delivery (using a course website) or via a CD-ROM. Typical forms of interactivity include activities involving dragging and dropping objects, entering text or numerical responses to questions. Simple Javascript enhancements can achieve a high level of interactivity via the Web. Flash programming is ideal for achieving this interactivity on both CDs and the Web. For students in remote areas (for example those situated on isolated mine sites) bandwidth and download times are an issue and therefore large video or interactive Flash files are better delivered via a CD-ROM. For remote students using these resources in distance education mode, support from a local mentor is vital. For students at other universities where the course is taught studying in local tutor is also a feature of most of these courses. Course modules developed in this way can also be used in a fully face-to-face environment. The modules described in this paper illustrate how this is being achieved.

We believe that the model of delivery that has been selected for our first series of course modules meets our primary aim, as well as pedagogical guidelines proposed by authors including Chickering and Gamson (1987) and Felder et al. (2000). The modules are designed to encourage active and cooperative learning, establish the relevance of course material by making clear links with real-world activities and provide the students with explicit objectives and timely feedback on their progress.

The greatest challenge in remote delivery of the courses is provision of an interactive learning environment for students, and this has been the focus of significant pedagogical design effort. This is fundamental to development of a ‘world class’ curriculum. Course modules developed to date all focus heavily on the link between doing and learning (Jonassen, 1998), providing students with a range of meaningful learning activities that in many cases contribute to production of a final assessable product.

The use of Flash in the Virtual Consultancy enables designers to create a fun, colour-intensive environment whilst maintaining small file sizes. Download time is a crucial factor when catering for remote students.

Experience tells us that most students in our program, particularly undergraduate-level students, are predominately assessment driven. Learning objectives are deliberately aligned with activities and assessment tasks in the course modules, so that the ‘hidden curriculum’ (Biggs, 1999) mirrors the visible curriculum.

A final pedagogical aim of the course modules is a focus on applications of the new knowledge. Although the modules described in this paper do not follow a true problem-based learning model, they can be described as ‘goal-based’ (Ip and Naidu, 2001). Students are presented with an assessable task early in the learning process and are required to define their problem and then devise a solution during the course of the learning process. This forms the bulk of course assessment.

Current course model
Several course modules have been developed or are under development at the University of Queensland. They include:
- Process Simulation and Control
- Communion, Classification and Liberation
- Physical Separation Methods: Gravity, Magnetic and Electrical Separation
- Plant Survey Execution (jointly developed with the University of South Australia)
- Circuit Design and Modification Philosophy
- Flotation Systems
- Calculation/interpretation of Recovery/Size Data (jointly developed with the University of South Australia).

The first of these courses was developed in 2000 and has been described in detail in an earlier publication (Drinkwater et al. 2001). The modules can each stand alone as a short course or be combined with others to make 2-unit mineral process engineering courses to fit within standard undergraduate programs.

As implementation may take place differently at different universities, the modules are designed to be delivered in a variety of ways, ranging from conventional lecture/tutorial/practical (fully face-to-face) format to remote delivery (on-line) format. Although student/teacher and student/student interaction is fundamental to the pedagogical design, the form of interaction is not critical to a successful learning outcome.

A ‘Guide for Instructors’ has been prepared for each module and explains how the resource material is to be used. This was considered necessary, as a lecturer who was not involved in the development will often be facilitating delivery.

The course modules each consist of the following:
- A printed workbook (or learning guide), containing a week-by-week guide to the course structure and learning activities, but minimal content. This provides the module framework and directs students to relevant readings and other materials they need to access. It also includes many learning activities to be undertaken by students as they work through the material.
- A set of Powerpoint lecture slides to support the workbook. These are largely pictorial and provide the context for much of the technical material covered. Note that the lectures are not the central learning resource, and instructors are told not to distribute the slides as ‘lecture notes’, as the workbook covers all the relevant material in a more complete and structured manner, and pictures are made available on the course CD.
- Selected readings (about 2 per week) and reference material, bound into a course ‘Reader’. These include equipment catalogues, process plant flowsheets and case studies which students can refer to when working through their assessment tasks.
- Summary notes which cover the technical fundamentals of the subject material, where this material is not available in the standard textbooks. These have been included at the back of each workbook for easy reference. These are based on traditional ‘lecture notes’. Again, note that these are peripheral rather than central to the course.
- Interactive learning activities on CD-ROM. Additional visual material such as flowsheets, pictures and
diagrams is also included on many of the CD-ROMs where it is available. The CD-ROMs make use of Flash and Quicktime technology which allows developers to include animation, video, audio in an interactive interface. Constructive feedback that doesn’t immediately provide the correct answer but is designed to refer students to the relevant learning resources so they can find the answers for themselves is an important part of the design.

• The course WebCT site, provides opportunities for regular student/teacher and student/student interaction and is a fundamental resource for remote delivery. The central feature of the web-site is a discussion forum that allows students to interact with one another and with the course instructor. Discussion tasks based on course topics help to structure the discourse in the Bulletin Board. Additional features such as on-line activities and quizzes are also incorporated into this site further enriching the learning experience for students. The course web-site can also be used when courses are run locally as these features will still enhance the learning experience for students.

- World-class teaching and learning tools
- Robust content management capabilities
- Complete personalization of the learning experience
- Dynamic learning information management
- Enterprise-class platform architecture.

Examples of some of these features are shown in Figures 1–6.

Each module is introduced and managed via weekly chapters in the workbook. This structure needs to be reinforced by the course instructor, either in weekly face-to-face sessions or via the web-site. Students are asked to submit an assessable item or activity each week, making it necessary for them to make regular contact with the instructor. Many of the weekly activities can be done in groups, and this feature is deliberately designed to encourage discussion, negotiation of meaning and other interactions which should assist the students’ construction of knowledge.

The bulk of the module content is contained in the specified textbooks, the summary notes provided with the workbooks and the course readings. Links to public websites and some material on CD-ROM is also provided.

There are two reasons for presentation of resource material in this way. The primary reason is that there is no point re-writing material that is already well presented in the literature. That should not be the focus of teaching activities, instead, instructors should concentrate on assisting students in learning activities requiring use of the knowledge. The second reason for encouraging students to access content from the textbooks and technical literature is that the student will learn efficient ways of accessing the material and will be more able to access the material as they need to in their working life. This is a valuable long-term learning skill.

Although the design allows for a situation where students are working entirely on their own, students generally learn best when opportunities are provided for face-to-face interaction and local tutors or lecturers should be involved in the course modules where possible. It is not essential that the local tutor be an expert on the course content, but it is important that they are supportive of the students learning efforts, especially with undergraduate students.

Implementation

Trial of the first module, Process Simulation and Control, was conducted in semester 2, 2000, with a group of local undergraduate students at UQ. That course was repeated in 2001 and 2002. A similar course, Practical Modelling and
Tutorial exercise #1

List mineral industries that employ gravity separation processes and specify typical equipment used. It may help if you address the following points, i.e.

1. What is the carrying medium in the separator?
2. Concentration ratio
3. High or low G?
4. Is the technology new or old?
5. Is the equipment used for high or low throughput process?
6. What is the size range of the process feed?

Use the Table provided at the end of this workbook for your answer and submit it to your lecturer at the start of the Week 2 lecture.

What was Lecture 1 all about?

Write down what you think were the main points of this introductory lecture:

1. .................................................................
2. .................................................................
3. .................................................................

Simulation, has been run twice for similarly aged students at the University of Toronto. All courses were taught from Brisbane, and Toronto students had local support in the form of 3 workshops on the material. Feedback from these groups was invaluable and has contributed substantially to the development of subsequent course modules. Indeed, there was a substantial reorganization of topics and assessment tasks during the early trials, as initial student responses were evaluated. The main focus of the reorganization was a change in the
The graph shown above represents the equation \( t_{10} = A^*1 - \exp(-b*E_{cs}) \). To determine \( A \) and \( b \) for this ore, we must select \( A \) and \( b \) values that result in the best fit for all points in the graph.

Some of the subsequent modules have been trialled during 2001 and 2002. Many of the trials have been run in a fairly traditional setting with local students, but using the course workbook and reader and reducing the contact hours. The 'lecture' time was divided between supervised student learning activities and slide presentations, which were then

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**Figure 4.** CD-Rom delivered course resources: Comminution module

**Figure 5.** Electronic tutorials can be provided on CD-Rom or via the course website.
made available on the course website. The slide presentations were designed to provide a knowledge framework with a minimum of content. Students were able to review the content more fully in their private study time. Feedback suggests that students responded well to this delivery style. More substantial trials of these modules using students at remote institutions are being planned.

Questionnaires about the form of module delivery were supplied to some of the students for their feedback, and the course material was also circulated with similar questionnaires to other academics. Feedback covered the general course design as well as specific aspects of delivery. The responses indicated that students like the workbook, while some of the lecturers found the format ambiguous. This may be because the students immediately react to the student-centred focus while lecturers find it confusing.

All respondents liked the goal-centred approach and the provision of structured activities aligned with the learning objectives. Students appear to like it because it provides direction for them and hence maximizes their chances of getting good grades. Lecturers may well like it because they can see that it supports the learning objectives. The fact that the same activity does both things is evidence of constructive alignment, which was a major focus of the pedagogical design.

Feedback also indicates that the format of these modules is unfamiliar to students and potential instructors, and that special instructions need to be provided to both groups. The ‘Guidelines to Instructors’ is therefore a critical component of the package and needs to be carefully thought through. Although students have information in the front of their workbooks, instructors need to be aware that students may need additional reinforcement wherever possible.

Changes to the course material prompted by the feedback from these trials will include:

- regular assessment tasks so that students have to engage with the learning material on a weekly basis
- more summary pages and a running checklist of tasks for the major project
- provision (probably via the website) of detailed calculation examples and model answers.

**Summary and conclusions**

The MTEC course development program is still in fairly early stages and is very much a work in progress. Many revisions of material are likely as more feedback is received over the next few years, especially after implementation. These early modules should be seen as a starting point for the process.

The dual goals of good pedagogical design and appropriate use of technology will be kept in mind during future development. The 7 principles of good teaching practice suggested by Chickering and Gamson (1987) are a good reference point. Using these, a more specific set of guidelines is suggested for the MTEC modules:

- Focus on student learning outcomes
- Get away from transmission
- Make appropriate use of communications technology
- Integrate learning activities
- Enhance flexibility of delivery
- Maintain high standard of content
- Start with a problem.

It is with these in mind that we hope to realize the Minerals Tertiary Education Council’s stated aim of providing the best available undergraduate and professional development education.

**References**
