

4 *Mining Engineering Education*

Upgrading Miners Knowledge through Website Learning on Mining Methods for Improved Safety and Productivity

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ABSTRACT: Mining Engineering Courses worldwide is in the process of continuing restructuring to meet the challenges and changing demands on mining engineering education. This is particularly pertinent in Australia as mines are highly mechanised as well as being in remote locations and away from educational centres of learning. An on-line interactive student resource on longwall mining has been developed at the University of Wollongong to serve as a supplement to formal teaching of mining engineering students enrolled in the subject of Underground Coal Mining Methods. The website (<http://www.edu.au/enp/current/longwain>) was then circulated to students and to various industrial organisations seeking their comments and advice for the future directions of this type of learning system. There was a general desire by various industry personnel to use this website for industry training, as well as for student learning.

1 INTRODUCTION

All mining engineering institutions worldwide including those in Australia teach core mining methods subjects to undergraduate students. The techniques of mining are best demonstrated when formal lectures are supported by field visits and hands-on practical experience. Where active mine sites are in close proximity to tertiary institutions, this is not normally a problem. Unfortunately most mine sites nowadays are remotely located from universities and educational institutions offering mining programs. In recent years large group access to local mines has been less than convenient. This makes the learning of certain mining methods a difficult task for students. Conventional teaching methods are to use static overheads and sometimes videos to explain simple operations to students and concept of equipment sizes and three-dimensional visualisation of unit mining operations are not always easily grasped by students. As a consequence, an on-line student resource on longwall mining has been developed to;

- serve as a supplement to formal teaching of longwall mining to students enrolled in the subject of underground coal mining methods,
- gain a better understanding of longwall mining in each student's own time and own pace,
- allow informal on-line interaction between students and lecturers by incorporation of a self-assessment component into the package,

- keep a breast of latest information and technologies used in Australian mines as the website is maintained dynamic with regular updating, and
- gain access to various statutory mining legislation's and laws as the website is linked to various government organisations and legislative bodies websites.

2 PROJECT DEVELOPMENT

A research assistant with mining engineering qualifications was recruited to develop the website. Reliance on a trained mining engineer was necessary in view of the nature of underground mining operations not being easily understood and visualised by others not trained in the discipline. Developing the website in-house provided an opportunity to master skills for future development of other sites as well as regular upgrading of the existing website. The initial introduction is to describe and illustrate the basic elements of longwall mining commencing with a basic definition of longwall mining and expanding to more complex issues related to the operation and problem solving associated with longwall mining. Accordingly, the structure of the developed website on longwall mining falls into the following components;

- a) general introduction to longwall mining
- b) general design and layout of longwall mining

- c) longwall mining machinery and equipment
- d) ventilation and environmental aspects of longwall mining
- e) geomechanics and ground control in longwall mining
- f) longwall change over techniques
- g) punch longwall mining
- h) glossary of longwall mining terms and references, and
- i) student and staff interaction.,

The website was written in the standard html format that is used on the internet. Access to the site is via any internet browser (i.e. Netscape Navigator or Internet Explorer) and the address of the website is <http://www.uow.edu.au/eng/current/longwall/>. One of the aims of this project is to present the information to the students in a user friendly and technically attractive style. The subject area that this website was designed for is a very descriptive subject and students previously undertaking this subject have found it difficult to comprehend and imagine in comparison to a real field situation. The incorporation of various video footage on actual coal mining operations and equipment functioning have contributed significantly to students' better understanding of the subject.

3 WEBSITE CONTENT

The technical content of the website is based on class lecture notes of the academics involved in teaching the various longwall mining subject components. This is further supplemented with technical material from industry personnel in the field as well as specialist mining consultants. The reported case studies and the future ones to be incorporated will be supplied from mining personnel and expert industry consultants. Although the website is linked to various national and international websites it will not be used to actively promote any company, product or alike. The website's primary function will be for educational purposes only, both for students and for knowledge upgrading of mining industry personnel. The inclusion of a self-assessment component is vital to the credibility and acceptability of the site. A method of determining the competencies of persons and their knowledge of the topics is becoming more critical in view of the mining legislation direction for future training of mine personnel working at the longwall face in Australia. Another section needs to be developed for the number of instances for the recovery of longwalls from disturbances of ground or inadequate maintenance of equipment or incorrect operation of the equipment. There is a lot of case history in Australia and overseas which has allowed

innovative techniques to be developed and would also save many millions of dollars to the mining industry.

To make it easier for students to use the site a standard/template was developed and this structure was incorporated onto every web page. A general view of the front page of the website can be viewed in Figure 1.

The structure used for this website was as follows;

3.1 Universal navigation system

This system allows the users to move around the web site with ease. The agreed system consists of a simple menu bar that is located in a column on the left-hand side of every page. At the top of the menu bar is the Mining Engineering logo of the University of Wollongong. Below the logo is a list of pages/modules that could be accessed from that particular page. To the left of each of the menu buttons is a mining icon (the well-known hammer and pick crossed) used to indicate the user's current location on the website by making the mining icon turn green. Located at the bottom of the menu bar on every page are four 'global' navigation buttons;

- HOME: Returns the user to the front page of the web site.
- GLOSSARY: Takes the user to a comprehensive list of terms and their definitions that are associated with longwall mining.
- REFERENCES: This button takes the user to a list of references that are associated with longwall mining, enabling the students using the web site to further research longwall mining from these particular references. The students can also check the University of Wollongong's on-line library catalogue to see if the references listed are available at the library.
- TOP: This button allows the user to immediately return to the top of the viewed web page when they have scrolled down to the bottom of it.

3.2 Content

The content of the web page takes up the remaining space left from that used by the navigation system. The content is presented in such a manner as to allow the student to read about a particular topic and then view a graphical diagram of that topic. The lecture material incorporated into the web site is well researched to accurately portray current longwall operations in Australia.

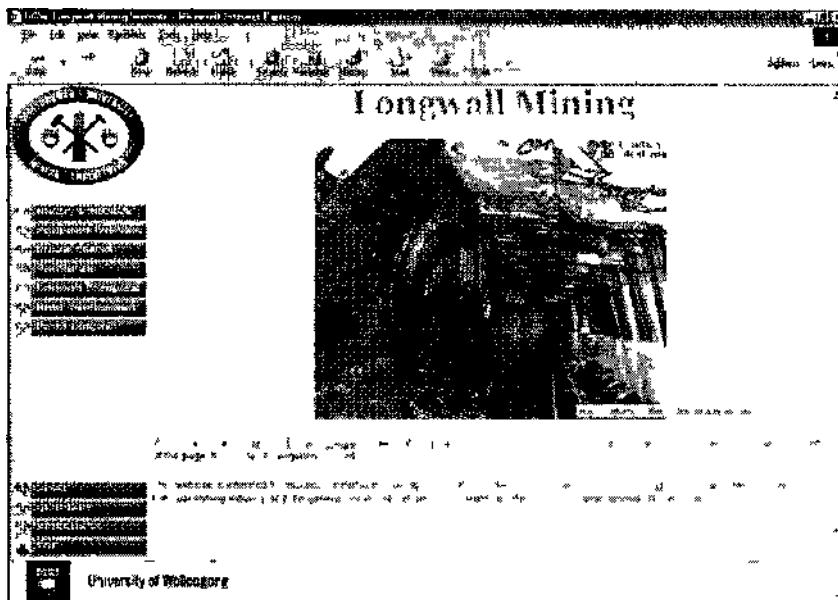


Figure 1 Front Page of the Longwall Mining Web Site

When the user accesses the site the index page in Figure 1 is displayed on their computer screen. A banner is incorporated at the top of the index page that says "Longwall Mining". Beneath the banner is a photograph of a modern longwall face from a current Australian Longwall face operation. In the navigation bar of the index page there is a series of menu buttons for the various learning modules that are available to the viewer. The topics incorporated into this site are:

3.2.1 History and methods

This module provides an introduction into longwall mining in Australia and throughout the world. It incorporates a short introduction into the basic concepts of longwall mining and the various methods that can be used to extract coal by longwall mining. A unique feature of this module is that it contains details of every currently operating longwall face in Australia including,

- longwall production figures for the last calendar year,
- equipment used at each longwall mine site,
- layout plan of each longwall site,
- coal seam mined,
- coal transportation,
- method of underground access,
- contact details of the sites,
- geographical location,
- commencement date of longwall mining operations

3.2.2 Equipment overview

A thorough description of longwall face equipment is described throughout longwall faces. These include,

- coal shearer
- coal plough
- powered supports
- armoured face conveyor
- pantechicon
- beam stage loader
- communications
- environmental

3.2.3 Ground control

An important aspect of longwall mine design is to understand how the surrounding ground stratification reacts when a tunnel is driven through it. The general stress build up around a longwall panel is described and demonstrated graphically as shown in Figure 2.

3.2.4 Ventilation

The design of a ventilation system for a longwall mine is dependent upon the geological and atmospheric conditions found at each individual mine site. Many factors have to be considered to determine the most suitable system of ventilation.

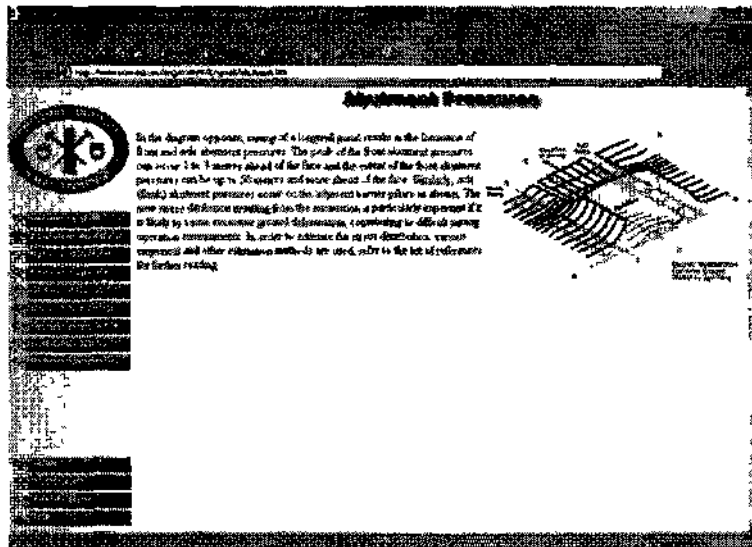
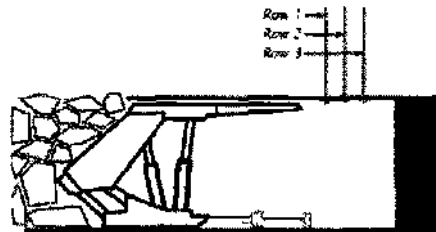


Figure 2 Longwall panel abutment stresses.

3.2.5 Longwall Changeover

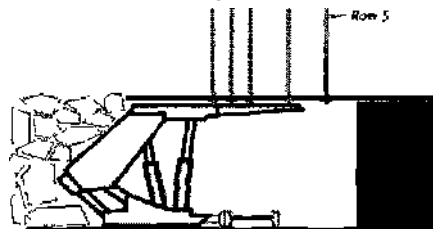
Once a longwall panel has been fully extracted the longwall equipment is dismantled and moved to a new panel. This operation is called a longwall changeover. The sequence of face preparation for equipment salvage is shown in Figure 3.

Bolt Up Sequence Stage 1



Cut from the tailgate in 20' chock sections. Place 1 "w" strap over the top of the chock (ie perpendicular to the face) anchored with 2 bolts set at 6.8 metres. Set rows 1 & 3 after row 2 at 7.3 metres & 6.3 metres

Bolt Up Sequence Stage 3

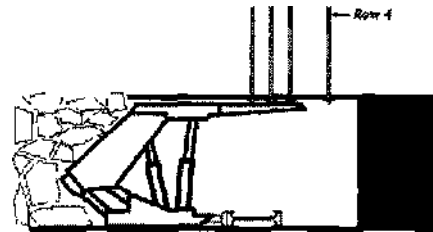


Advance the pans and cut from tailgate to maingate and back to tailgate and advance the chocks. Set row 5 at 4.3 metres.

3.2.6 Punch Longwall

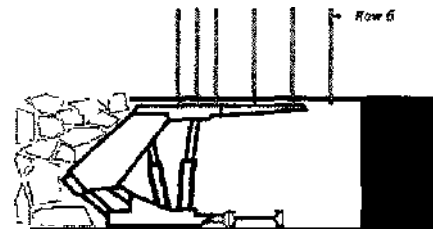
A method of longwall mining from the highwall of an open cut operation, in which the stripping ratio far outweighs the production cost of coal mined as shown in Figure 4.

Bolt Up Sequence Stage 2



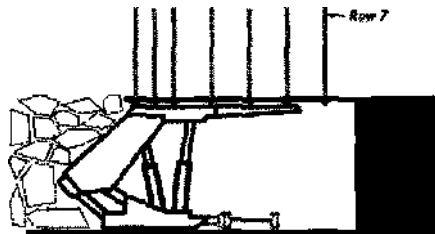
Take the shearer to the tailgate. Advance the pans and cut from tailgate to maingate and back to tailgate, then advance the chocks. Set row 4 at 5.3 metres.

Bolt Up Sequence Stage 4



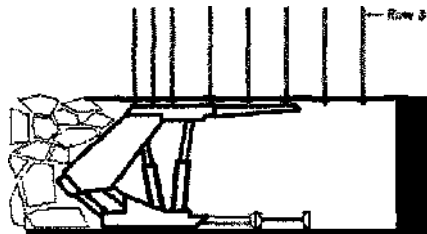
Advance the pans and cut from tailgate to maingate and back to tailgate and advance the chocks. Set row 6 at 3.3 metres.

Bolt Up Sequence Stage 5



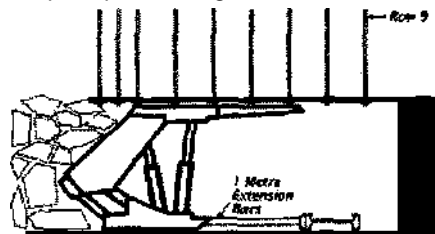
Advance the pans and cut from tailgate to maingate and back to tailgate and advance the chocks. Set row 7 at 2.3 metres. The chocks have now reached their final position. The next 2 shears that are to follow will provide face for the chocks to be removed.

Bolt Up Sequence Stage 6



Advance the pans and cut from tailgate to maingate and back to the tailgate. Set row 8 at 1.3 metres.

Bolt Up Sequence Stage 7



Install the relay extension bars. These allow the pans to be pushed a further 1.0 metre without the chocks needing to move. Advance the pans and cut from the tailgate to the maingate and back to the tailgate. Set row 9 at 0.3 metres. Set an extra bolt every 2nd chock for mesh at an angle over the coal face.

Final Bolt Up Sequence Stage

The face is meshed using angled bolts from stage 7 and bolts where needed to hold the mesh onto the face. A rib strap is installed along the bottom of the mesh and bolted every 1 metre.

This now completes the bolt up cycle. The bolts that were used at this mine were 2.1 metre mild steel bolts. A mild steel bolt was used rather than a high tensile bolt because it is able to bend more.

The conditions at South Bulli did not require support to be installed at the maingate or tailgate. Some other mines in the Illawarra region do provide support to the gate roads. This support is in the form of either:

- Polyurethane Resin injections into the tailgate, maingate and face areas
- Cable Bolts

Bolt Up Final Plan View

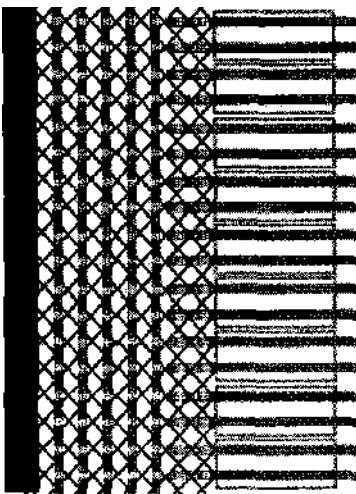


Figure 3. Sequence of longwall face preparation for equipment salvage.

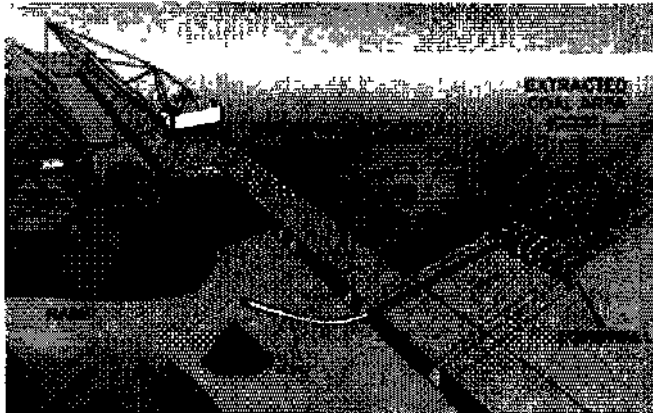


Figure 4 Punch longwall mining

4 WEBSITE SURVEY

In designing any computer interactive system, which requires user participation the friendliness of the system, needs to be evaluated to determine how useful the information portrayed, together with learning retention time, the speed of performance and rate of errors etc. In web interface design, the time required by the browser to load the material together with the navigation controls being developed to prevent loss in hyperspace needs also to be assessed. These concepts are important factors of Human Computer Interaction (HCI), in determining user friendliness usually referred to as 'usability' [Shneiderman 1992]. In assessing usability, information can be collated in a number of ways from observations, interviews, keystroke capture and questionnaires of the users ability to become proficient with the system. There are several leading authors in the design of user interfaces including Nielsen, a leading guru of web interfaces. Nielsen uses a technique of 10 heuristics for assessing usability for assessing web site interface design [Dumas 1988, Shneiderman 1992, Nielsen 1994, Tilson et al 1998, Bevan 1998]. In terms of evaluating the web site a survey of users was devised using some of the heuristics concepts together with a functionality evaluation. Initially the survey was conducted using students which have had exposure to the subject of longwall mining. The aim was to gather their input and ideas for further development on the website. The students navigated through the website for approximately half an hour and were then asked a series of question at the conclusion of the session. Some of their responses are given below

"It is great because you actually get coloured pictures, movies etc right where your information is so you visualise what your reading"

"Yes, very helpful. I wish we had it for our sessions work "

"It helped my understanding of longwall mining by a great deal due to the videos and diagrams. "

"It helped a lot, doing a 2nd year subject it is the V time you are exposed to anything mining related and the concepts can sometimes be confusing but here they are set out logically. "

5 INDUSTRY RESPONSE

The following comments were received from different industry quarters;

- *"As a non-engineer I found it a very easy site to navigate, with easily accessible links The quality of writing is excellent, and I was able to easily understand the concepts involved. "*
- *"I would like to congratulate you on the new website, it is very good and extremely comprehensive. The website is a good general introduction to the areas of longwalls. It would be enhanced by the addition of two areas. (i) There needs to be a method of determining the competencies of persons and their knowledge of the topics, this is becoming more critical with the way mining legislation is going for all training in the future. Each of the sections needs an assessment module attached if this is intended for industry training, (ii) Another section needs to be developed for the number of instances for the recovery of longwalls from disturbances of ground or inadequate maintenance of equipment or incorrect operation of the equipment. There is a lot of case history in Australia which has allowed innovative techniques to be developed and would also save many millions of dollars to the industry. The case histories would have*

to be sought from the various mines who have had longwail failures due to those criteria I gave you and extended delays. "

6 CONCLUSION

The website on longwail mining is developed primarily as a tool for effective teaching in tertiary education. The website has been placed into the public domain to assist in upgrading and training of mining industry personnel as well as raising awareness of the mining operation to the public in general. The website would be a valuable source and a useful library for those interested bodies in remote regions and rural areas of Australia and also any interested persons throughout the world. Although the website is interlinked to various national and international websites. It is purely an educational website that in due course will also be a website for advanced training in various aspects of mining engineering which will cover more complex issues for improved safety in mining operations.

ACKNOWLEDGMENTS

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Use of an Integrated Mining Software Package for the Training of Mining Technologists

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ABSTRACT: As computers become part of every engineering activity, it is essential that mining technologists and engineers be exposed during their education to specialised software and hardware. The field of mining engineering becomes more computerised every day. New computer programmes and algorithms are developed to solve the most difficult mining problems and at the same time, new hardware is produced to run these programmes faster and more efficiently. This paper describes how mining software is used at the Technological Education Institute of West Macedonia, Greece. An integrated mining software package is used as the basis for training mining students in the application of computers to geotechnical and mining works. The benefits and problems of this integration are analysed.

1 INTRODUCTION

1.1 *Mining Industry and Computers*

The wide acceptance and application of computer software and hardware by the mining industry is common knowledge. The mining field is complex, involving many different sciences, and this is one of the reasons why computers are so widely applied in this field. Computers are involved at almost every stage of a mining project. From exploration and reconnaissance to ore processing and production scheduling, highly sophisticated software is used to ensure quality of work as well as speed and efficiency.

Twenty years ago, mining was at the beginning of a technological outburst as the specific needs of this field attracted the attention of the computer industry. Since then, a number of software companies providing specialised mining, geological, and environmental software and services have appeared. Universities and research institutes worldwide have dedicated large amounts of financial and human resources to the research and development of computer algorithms, which were then integrated into small task-specific computer programmes and large multipurpose software packages.

1.2 *Introducing Computers to Mining Education*

As a result of all these developments, the educational programme of universities training mining technologists is changing to incorporate computers

as a subject and as a means for training. To meet the growing challenge of computerisation, education providers must integrate computer hardware and software into the classroom. There are several questions to be answered before this integration takes place. The most important one is probably, "What facilities and training are vital to the education of mining technologists?" Next, it must be decided how to best integrate this technology into current curriculum as well as introduce new courses which simultaneously stress engineering fundamentals and computer applications (Procanone and Cameron, 1985).

1.3 *The Case of the Technological Education Institute of West Macedonia*

The Technological Education Institute of West Macedonia has been training mining technologists for almost fifteen years. The recently reorganised Department of Geotechnology and Environmental Engineering aims at the production of technologically educated engineers that receive the necessary knowledge covering the fields of mining and geotechnical works as well as the environment and its restoration. With the introduction of new courses such as GIS, remote sensing, geostatistics, geoinformatics, and the application of computers to geotechnical and mining works, the department moved towards the integration of specialised computer software in the training of its students.

Recently, the department purchased VULCAN, a 3D-software package covering most aspects of

mining, to form the basis of the course "Applications of Computers to Geotechnical and Mining Works" and complement other courses. The reasons that led to this choice as well as the concept of using such software in training will be explained. As it will be shown, there are great benefits from the use of such software in education.

2 EDUCATIONAL ENVIRONMENT

2.1 The Course

Before the discussion of the integration of VULCAN into the course, it is necessary to give a brief description of the facilities and organisation of the department relative to this course.

The course "Applications of Computers to Geotechnical and Mining Works" is lectured to third-year students of the department. Basic computer knowledge is a prerequisite, while the students are also exposed in previous semesters to geology, surveying, mapping, CAD, and other important subjects. The aim of the course is to train students in using computers for project management, mine design, optimisation, and scheduling, as well as financial management.

2.2 Facilities

In order to cover the engineering part of the course, the department purchased the VULCAN 3D Software package from Maptek/KRJA Systems Ltd. A number of VULCAN licenses were acquired and a laboratory was set up with PC workstations running the software, a plotter, and a wall projection system to be used during lecturing as shown in Figure 1.

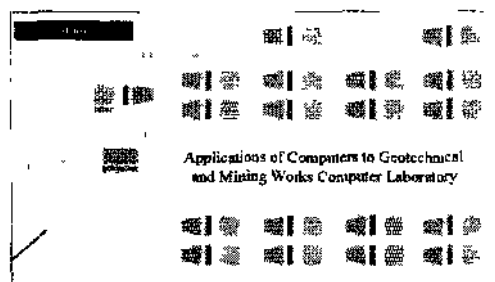


Figure 1: Plan view of laboratory arrangement for the course of Applications of Computers to Geotechnical and Mining Works.

The students form groups of twenty (maximum) to ensure that everyone gets hands-on experience. Each student will be using VULCAN at least four hours per week in a number of mining, geology, and environmental engineering tasks. Unfortunately, it is not possible to have free access to the laboratory as yet.

In principle, access must be as free and as unstructured as possible. A problem seen with many students is a feeling of unease when using computers. Utilisation of computer facilities allows one to become acquainted with their benefits and capabilities. It is one of the main considerations to find a way for the students to access the laboratory whenever they want while ensuring the safety of the equipment and software.

2.3 Lecture Notes

A set of lecture notes was prepared based on professional VULCAN training material from Maptek (McCallum, 1996) and related material from international sources (Badiozamani, 1988). Included in the notes are several tutorial exercises demonstrating various aspects of the use of mining software as well as basic principles of computer modelling and simulation. These notes are not meant as a replacement for other courses covering the theory behind mine design and process modelling. Computer analysis of a problem should not replace teaching design fundamentals in the classroom. Although such a course of action may make a student very capable at using the software, it can lead to deficiencies in the primary concepts vital to the engineering of a mining system.

2.4 Course Organisation and Student Assessment

Lecturing is organised in two-hour sessions twice a week. During this time span, the students are presented with a task and the primary data necessary to complete it. At the same time, the basic steps and principles in solving each problem are explained. The students need to comprehend the problem they need to solve and the approach to its solution using computer software. They also need to get familiar with the software-specific operations necessary to carry out the task. This is not one of the aims of the course but a necessity. The primary objective of the course and of the introduction of sophisticated computer software is to make students capable of using their knowledge of the physical behaviour of systems to solve problems and implement new designs and not to become experts in using the particular software package. It is impossible, though, to achieve this objective without some knowledge of the use of the software.

The students are assessed by means of a short oral examination involving the use of the software and its application to one of the tutorials from the course. During this examination, the students are marked for their understanding of the underlying processes, their ability to handle and visualise 3D data, and their ability to use data creatively to reach the solution.

3 CHOICE OF SOFTWARE

3.1 *Single Package vs. Multiple Programmes*

The choice of the most adequate software package to train mining technologists is not the easiest of tasks. The first decision to make is whether it is going to be a single package covering many different aspects of mining or a number of different smaller programmes each specialised in one area. From our point of view, the single package covering as many applications as possible is preferable. This is the case for several reasons. Firstly, students will only have to learn one user interface as all programmes of the single software package behave in a similar way. In this way students can move between the various programmes and applications without having to learn yet another environment. Learning the user interface of a particular computer programme is not one of the educational goals. Another reason is that it becomes easier to combine results from different applications, and there is no need for file conversions and similar time-consuming procedures.

3.2 *Degree of Sophistication*

The degree of sophistication of the software probably contributes little to the overall education of an engineer. There is no need for undergraduate students to be exposed to the latest and most sophisticated software during this course. However, in the case of mining software, the degree of sophistication usually shows the degree of usability and determines the range of applications covered. Thus it is critical to choose a software package that will meet the educational goals of the course. Choosing a sophisticated software package is important if the same software is to be used for research by graduate students and lecturers.

3.3 *Computer Graphics*

Nowadays, software is also judged on one very important issue: 3D graphics. Computer graphics have developed rapidly over the past decade. The computer industry provides the hardware necessary to run software generating advanced 3D graphics in real-time mode. Advanced 3D graphics allow the precise visual representation of engineering designs and improve communication among people involved in the same project. In the case of education, this means better communication between lecturer and students and less effort from the latter to understand complex designs as well as the intermediate stages leading to them.

3.4 *Maps and Reports*

Generation of maps and reports is another area of consideration when choosing mining software. It is essential for students to be able to see the results of their work printed on paper and to an appropriate scale. Reports from various calculations are also important, as they are necessary during tutorials and for the write-up of project reports. Both maps and reports give students a feeling of how things happen in a real professional working environment.

3.5 *VULCAN 3D Software*

Maptek's VULCAN 3D Software has been chosen as the software used during lectures and tutorials for the course. VULCAN is one of the leading software packages in the field, providing great functionality and covering a very wide range of applications, including:

- all aspects of geology and mine planning
- open pit and underground mining
- modelling of metals, coal and industrial minerals
- surveying
- environmental management
- urban planning
- civil engineering
- road design
- 3D GIS
- oil & gas
- defence applications

VULCAN enables the translation of complex data into visual information. This visual information enhances students' understanding of complex mine designs and their ability to understand three-dimensional objects, particularly underground.

The various phases of a mining project can be clearly explained through a number of tutorials based on the advanced capabilities of the package. During the exploration phase, for example, students can see how information is collected from different sources, such as:

- exploration drilling
- assays (soil samples, drill core)
- surveying instruments
- geophysical and geochemical surveys
- digital terrain models
- scanned historical maps
- aerial photography

During the course, students get exposed to VULCAN-supported modelling techniques such as triangulations, grid models, block models and contours. They also get a taste of different numerical techniques used to estimate values when calculating grids and block models such as Delaunay triangulation, polynomial trend analysis, kriging, inverse distance, and nearest neighbour.

VULCAN's user interface is easy to learn even for students with no prior computer knowledge. When familiarising them with the system, most time is dedicated to manipulating the view and projection of models on the screen rather than learning menus and commands. Playing with the projection, zoom, pan and rotate tools in VULCAN's 3D graphical environment improves the students' ability to understand three-dimensional images and computer graphics. It also enables them to be productive during the tutorials as they can manipulate various models and other visual information fast, leaving time for more important modelling work.

Naturally, there have been some problems found during the course. As the software is quite sophisticated, there are numerous menus and functions that discourage students with little knowledge of computers. Most of the dialogue boxes and the various panels contain many options and tick boxes, all with titles and explanations in English. Some of the students have problems understanding them, meaning that the tutor has to put extra effort into explaining and translating the text in order for the tutorials to be carried out by all students. However, there is no guarantee that translating all this mining terminology into Greek would be particularly helpful as undergraduate students are not fully familiarised with mining terminology anyway.

4 HARDWARE REQUIREMENTS

4.1 Workstation System

The heart of the laboratory is a number of Intel-processor-based PC workstations. They use the Pentium II & III processors able to run VULCAN software at acceptable speed. The software requires large memory resources; therefore, a minimum of 128Mb of RAM is set as the standard. The large surface and solid models produced by VULCAN also require large amounts of virtual memory and, therefore, fast and high capacity hard disks are absolutely necessary. The workstations are networked via Ethernet to allow easy transfer of data between them.

Graphics are a very important issue. VULCAN's graphics engine is based on OpenGL. A quality graphics adapter with OpenGL acceleration can have a great effect on the workstation's performance when visualising large complex surface models with shading and textures or large block models. Large monitors are also important. A 17" monitor should be the minimum for a VULCAN workstation.

4.2 Peripheral Systems

These include an AO plotter and a backup device to store the large databases produced by the software.

The plotter should support the HP/GL2 language. A Postscript A4 laser printer could be useful for printing reports and other course-related material.

5 APPLICATIONS OF COMPUTERS TO GEOTECHNICAL AND MINING WORKS

5.1 Overview

The aim of the course is to expose students to a number of real-life applications of computers in the field of mining and geotechnical works. Students must be able to see, through a set of tutorials and theory, how certain things happen in a real working environment using computers and sophisticated computer software. Clearly, it is not possible to cover every single application in great depth. There are time constraints as well as knowledge limits that determine the type of applications and the extent to which they are covered during the course.

The content of the course can be adapted according to the special characteristics of each student group. Some students are more computer literate than others and some students can understand 3D visual information better than others. This affects the speed of the course as well as the type of applications covered. These applications should, however, cover subjects such as exploration and reserve estimation, surface and underground mine design and optimisation, and production scheduling.

5.2 The Tutorials

The main part of the course is a set of tutorials that take place in the specially arranged computer laboratory. The tutorials are two hours long and cover application areas such as:

- *Mining software basics*: data sources, data structures, databases.
- *Computer Aided Design*: object design and advanced editing options specific to mine designs.
- *Surface and solid modelling*: triangulation modelling using the Delaunay algorithm and solid triangulations, advanced triangulation manipulation options, draping of photographic images and block model intersects.
- *Drillhole and sample databases*: samples from drillholes and other sources, compositing, basic requirements for database generation, database manipulation and 3D visualisation.
- *Geological modelling*: display, analysis and manipulation of lithological, analytical, structural and mineralogical information, profiling, and stratigraphic modelling.
- *Resource and reserve estimation*: advanced statistics, geostatistics, grid modelling, block modelling, contouring, reserve calculations and reporting.

- *Underground mine design and optimisation:* layout design including roadways, cross-cuts, panels, pillars, longwalls or shortwalls, and stopes, using specialised mine design options, and solid model generation using centerlines and cross-sections (primitives) or roof and floor polygons.
- *Surface mine design and optimisation:* top-down and bottom-up approach, ramp design, switchbacks, open pit optimisation using the Lerchs-Grossman algorithm, design intersection with topography and other features.
- *Road design:* combining horizontal and cross-sectional designs, multiple road sections design, design of super elevated turns and cross-falls for surface drainage, fly-over and drive-along viewing of the simulated road.
- *Production scheduling:* mine design breakdown to mining phases and blocks, analysis and determination of key scheduling parameters, long-term and short-term planning and scheduling.
- *Environmental management:* groundwater modelling, visual impact assessment, site monitoring, rehabilitation and contaminant control.

Each tutorial is fully documented in the course notes and the various steps are described together with the necessary VULCAN commands and functions. These commands are given hierarchically, i.e., the entire route to the command is provided, helping students to cope with VULCAN's massive menu structure and be more productive.

6 CONCLUSIONS

6.1 Current situation

In this paper, the use of an integrated mining software package for the training of mining technologists has been analysed. The choice of the software package has been explained. The way the software is used through a course titled "Applications of Computers to Geotechnical and Mining Works" has been described and various benefits and problems have been identified.

As it was shown, training students using such so-

phisticated software can enhance their understanding of how mining works in real life and how their knowledge of mining can be applied to produce complex mine designs and production scenarios. Students gain hands-on experience in applying estimation and modelling algorithms that they would otherwise only know in theory.

Visualisation of mine designs as well as geological information in a 3D graphical environment gives students a very good approximation of a real mining situation that is impossible to provide through other means such as drawings, diagrams or even plots and printouts. The ability to view the same design from multiple positions or in animation improves students' understanding of three-dimensional entities, from drillholes to complete mine designs.

6.2 Future work

So far, the software has been used only for the purposes of one particular module. Its integration with other modules as well as its use for research work and postgraduate studies is being considered. The software is also to be used for final year projects. All of these require proper time and organisation of resources. Improvements are also expected on the software package itself: a better graphical user interface and integration with the computer's operating system is on the way.

Generally, the concept of using such software is in its early stages, and it is expected to mature with time to give even more benefits to the department as well as solutions to current problems.

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Mining Engineering Postgraduate Education by Distance Learning through the Internet

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ABSTRACT: This work considers different schemes to assist the need of mining engineers for advanced postgraduate education. The work is conducted in two stages. In the first stage, a modified Delphi approach is applied to determine the teaching modules that mining engineers consider the most important and useful. Using statistical analysis tools, it is found that the market that the course addresses can be enlarged to include chemical engineers, metallurgists and industrial chemists, who display similar demand patterns. The second stage consists of an economic/technical analysis of five suggested alternative teaching modes. These scenarios include the options of distance learning (DL), studio-on-line and tutor-on-line DL using the Internet, experts delivering lectures in situ, and a traditional university course. The best option is identified by means of the cost benefit, while a sensitivity analysis is carried out to show the dependence of the expenditures on the cost variables.

1 INTRODUCTION

The establishment and operation of institutions of learning with high accessibility, course diversity and appropriate facilities scattered over a large area is an extremely expensive task. This is particularly true in countries with the topology and geography of Greece, with remote communities in small islands or in mountain regions. Students have to spend a great deal of time and money on their education if they decide to pursue a university degree by means of conventional education schemes (Croy, 1998).

Distance education presents an interesting alternative. The idea of DL has been around for a long time, while advances in information technology provide new modalities to assist the delivery of knowledge to anyone interested, regardless of place or time. Especially nowadays, the concept of delivering course material is shifting from the physical classroom to the virtual classroom, where there is a lack of direct face-to-face contact. Since 1969, the Open University (OU) in the UK has offered undergraduate degrees via a "virtual classroom" (Educom Staff, 1996). In the USA, the California Virtual University (listing 1000 distance education courses) and the Western Governor's University (a consortium of 18 states) are two of the most successful examples of partnerships formed to promote distance education as a viable alternative to classroom instruction (Koss-Feder, 1998). Computer-mediated communication (CMC) schemes appear as

substitutes to direct student-tutor interaction, and create the social presence that lacks in traditional distance learning courses (Tu, 2000). In these applications, the Internet presents the twin advantages of a powerful development platform in a familiar and user-friendly environment (Butler, 2000; Yanarella et al., 2000).

At the moment, the European Union is creating a network of European open universities and is providing substantial financial assistance. This situation brings immense opportunities for the development of DL schemes, while the recently established Hellenic Open University (HOU) can administrate such courses.

This paper considers the postgraduate education of mining engineers in high-managerial positions who have typically graduated over 20 years previously. Having left the classroom so long ago, they need to enrich and update their knowledge, while the nature of their job (which locates them away from the big cities where most universities are) has probably deprived them of a postgraduate degree. It is not the purpose of this paper to stress the importance of continuing education in an era of global information and competition (see Harrod and Townsend, 1998).

The work first applies a modified Delphi approach in order to determine the teaching modules that appear to be of great importance and use to a sample of mining engineers. Using statistical analysis tools, it is found that the course target audience can be

enlarged to include chemical engineers, metallurgists and industrial chemists, who display similar demand patterns. Based on the suggested course modules, the study continues with an economic/technical analysis of five suggested alternative teaching modes. These scenarios include the options of distance learning (DL), studio-on-line and tutor-on-line DL using the Internet, experts delivering lectures in situ, and a traditional university course. The best option is identified by means of the cost benefit, while a sensitivity analysis is carried out to show the dependence of the expenditures on the cost variables.

The paper presents the first attempt in the field of postgraduate education opportunities for mining engineers in Greece, and thus features elements of a forecasting activity. For this reason, the Delphi method is suggested, suitably modified to address the needs and practicalities of the present study.

2 METHODOLOGY

The Delphi method was initially developed at the RAND Corporation in 1950 by Dalkey and his colleagues so as to eliminate several negative effects produced by interacting individuals and groups in the process of decision making. Traditionally, this method has employed the use of advisers/experts in order to arrive at a consensus on the determination of the necessity of plans/actions and their consequences in the near future, as well as on the likelihood and timing of possible future events. These advisers/experts are queried independently on iterative questionnaires with feedback supplied between rounds by the group in charge for the whole project.

There are many versions, modifications and extensions of the Delphi method. One of these, called SEER (System for Event Evaluation and Review), introduces preliminary work for constructing an initial list of alternative scenarios to reduce the number of questionnaire rounds, thus saving effort, economic resources and time. According to this modification, the advisers/experts are asked to answer questions only in their area of expertise. In order to obtain answers of approximately equal importance/reliability, thus avoiding the otherwise necessary setting of weights on opinions according to the specialty of each expert (Fusfeld and Foster, 1971).

The three-stage Delphi version adopted here employs the use of a different set of advisers / experts at each stage in order to increase reliability and reduce the required time, cost and resources. For this last reason, the first two questionnaires were answered orally, while some preliminary

work, which should be performed by the experts during the first round, was actually done by one research group. The whole project lasted about 45 days, not including the background work done previously. It can be divided into the following nine steps:

1. Problem definition. Retrieval of information available. Determination of expertise required. Selection of advisers/experts. Preparation of the first questionnaire with the objective of selecting the topics that must be taught to the professionals whom the program is addressed to.

2. Personal communication with advisers/experts. Classification and processing of answers. Unification of topics into formal entities, corresponding to similar entities found in the teaching material provided by universities on Internet sites which are considered international leaders in the field.

3. Intermediate restructuring of the initial problem on the basis of these formal-teaching entities. Preparation of the second questionnaire with the objective of investigating ways of teaching/learning these entities by modern educational means.

4. Personal communication with advisers/experts other than those mentioned above (mainly tutors of HOU). Categorization and processing of answers.

5. Final restructuring of the problem on the basis of the relation between teaching entities and teaching modes. Formulation of teaching modules with the corresponding syllabuses. Preparation of the* third questionnaire with the objectives of (i) ranking the modules according to their importance for the potential postgraduate professionals, and (ii) obtaining feedback as regards topics probably not included in the initial list of modules (or topics incorporated within wide-ranging instead of stand-alone modules).

6. Circulation of the written questionnaire. Collection and processing of answers. Decision making on the final structure of the teaching program.

7. Design of alternative ways to realize the program.

8. Cost benefit analysis of the alternatives. Further investigation of each alternative solution by means of break-even point and parameter sensitivity analysis.

9. Decision making on the most beneficial alternative. Simulation of application aided by a specimen group of professionals exhibiting the characteristics of expected or possible candidates. Further improvement of the proposed solution.

Subsequently, we present the quantitative parts of this work, namely, the statistical processing of answers to the third questionnaire and the cost benefit analysis (included in steps 6 and 8, respectively).

Table 1: Statistical analysis for assessing agreement of the rankings within the sample of 14 mining engineers.

Module	R _i	R _i /m	s.d.	rank
Engineering economics	32	2.29	2.15	10
Environmental management	47	3.36	2.81	9
Human resources management	89	6.36	1.99	4
New technology & methods	59	4.21	2.06	7
Occupational health	115	8.21	1.64	2
Operations management	80	5.71	2.00	5
Reliability & risk analysis	49	3.50	1.89	8
Safety	117	8.36	1.95	1
Statistical process control	103	7.36	2.28	3
Total quality management	79	5.64	1.81	6
$n = 10, m = 14, w = 0.4892, x^2_T = 61.64$				
top-down: $C_T = 0.4701, x^2_T = 59.23$				
bottom-up: $C_T = 0.4569, x^2_T = 57.57$				

Table 2: Statistical analysis for assessing agreement of the rankings within the sample of 23 CEMICs.

Module	R _i	R _i /m	s.d.	rank
Engineering economics	67	2.91	1.51	10
Environmental management	82	3.57	2.45	9
Human resources management	143	6.22	2.32	4
New technology & methods	124	5.39	2.12	5
Occupational health	199	8.65	2.22	1
Operations management	101	4.39	2.86	8
Reliability & risk analysis	113	4.91	2.06	7
Safety	170	7.39	2.00	2
Statistical process control	146	6.35	0.84	3
Total quality management	120	5.22	2.39	6
$n = 10, m = 23, w = 0.3254, x^2_T = 67.36$				
top-down: $C_T = 0.2874, x^2_T = 59.49$				
bottom-up: $C_T = 0.3425, x^2_T = 70.89$				

Table 3: Statistical analysis for assessing agreement of the rankings in the joined sample of 37 professionals.

Module	R _i	R _i /m	s.d.	rank
Engineering economics	99	2.68	1.51	10
Environmental management	129	3.49	2.45	9
Human resources management	232	6.27	2.32	4
New technology & methods	183	4.95	2.12	6
Occupational health	314	8.49	2.22	1
Operations management	181	4.89	2.86	7
Reliability & risk analysis	162	4.38	2.06	8
Safety	287	7.76	2.00	2
Statistical process control	249	6.73	0.84	3
Total quality management	199	5.38	2.39	5
$n = 10, m = 37, w = 0.3648, x^2_T = 121.5$				
top-down: $C_T = 0.3305, x^2_T = 110.1$				
bottom-up: $C_T = 0.3654, x^2_T = 122.3$				

3 STATISTICAL PROCESSING

The ten modules included within the third questionnaire are listed alphabetically in the first column of Table 1. Fourteen professionals, all mining engineers, were asked to give marks in the form of ranks in descending order from 10 to 1. The ranking is according to the subjective judgment of each of them separately, and refers to the importance/usefulness of the modules. The Kendall coefficient of concordance was used to determine the degree of agreement among these rankings. The next columns indicate the sum of the ranks R_i ($i=1, \dots, n$), the mean, the standard deviation (s.d.) and the overall ranking. The Kendall coefficient for this sample is 0.4892; the significance of this value is checked through the relationship between this coefficient and the Friedman chi-square, x^2_T , i.e. $x^2_T = m(n-1)w$, which gives $y^2_T = 61.64 > j_{r, \alpha, C_T}$ where x^2_T are the tabulated critical values for confidence levels of 90% and 95% according to the chi-square distribution (m =sample size, n =number of teaching modules). Consequently, the null hypothesis that there is no agreement among the 14 rankings is rejected.

We also use a weighted rank correlation (after Quade and Salama, 1992) to put emphasis on those modules ranked high or low, performing a top-down or bottom-up examination, respectively. In the bottom-up examination, each original rank k is replaced by its Savage score (Iman and Conover, 1987), i.e., the sum of reciprocals $5, -\frac{1}{k}, \dots, 1/\&$. For

the top-down examination, the Savage scores are assigned in reverse order, since the reference is expressed in descending order. The corresponding test statistic C_T , for assessing the degree of agreement among the professionals, is used to calculate $x^2_T = m(n-1)C_T$. The resulting x^2_T is compared to the tabulated critical values of chi-square distribution for confidence levels of 90% and 95%.

Since the number of mining engineers in Greece is rather limited, i.e., 2,000 (only a small percentage of these work in mines, while this figure includes metallurgists), we decided to extend our study to chemical engineers, metallurgists and industrial chemists (CEMIC) in order to increase decisively the possible demand. It is worthwhile noting that the number of chemical engineers is about 7,200 and the number of industrial chemists is about 1,800 (out of a total of 8,200 chemists). Tables 2 and 3 correspond to the new sample of 23 CEMICs and the joined sample of $14 + 23 = 37$ professionals, respectively. In both cases, as well in the top-down and bottom-up analytical examination, we find the rankings to be in agreement. We can, therefore, proceed to cost benefit analysis based on an enlarged market which exhibits

significant uniformity as regards the demand for educational services (priority and intensity/emphasis on teaching modules).

4 ALTERNATIVES UNDER CONSIDERATION

The suggested postgraduate studies program is based on taught courses, examinations, projects and a dissertation. The course length is one and a half years, divided into three semesters. There are ten available modules, as discussed previously. Within the first two semesters of the course, each participant is entitled to take either the ten modules described, or a selection of five of his/her choice. In the latter case, the participant allocates the remaining course time to the thesis project, which is continued and concluded within the third semester of the course. The participants selecting the former option should spend the third semester on four small-size projects.

The following economic/technical analysis assumes a number of 120 participants scattered over many small and medium-size mining sites and industrial units in Greece. Our survey has yielded that 40% of the potential participants are mining engineers and the rest are CEMICs. To accommodate for the slightly different interest areas and educational backgrounds of the above categories, it is assumed that each module's material consists of a theoretical part, which is common to both categories, and an application part, which is tailored to the category in question. Note that this should increase the figures in some parts of the expenditures (for instance, the development of the course material).

Clearly, the average student (having graduated 20 years previously) should have particular difficulty in complying with the university's expectations. In this sense, the course design allows flexibility so that the length can vary according to the needs of the individual participant. Indeed, the student can attend the courses over a longer time than the prescribed one year or spend longer time on the project work. Accordingly, the analysis presented here is based on the average course length, which is expected to be two years.

The scenarios for continuing education consist of five distance and face-to-face schemes, including conventional and novel alternatives. The different cases considered here are:

1. Distance learning course.
2. Studio-on-line distance learning course.
3. Tutor-on-line distance learning course.
4. Experts deliver lectures in situ.
5. Traditional university course.

An economic/technical evaluation is performed so as to indicate the best options based on strictly economic criteria.

Scenario 1 assumes conventional DL, as in the case of the British OU or the recently founded HOU. In this scheme, the student, who may reside in a remote location, receives a package with the course material (carefully put together to assist the self-learning process). A personal tutor is assigned to each student, and student-tutor communication is mainly over the phone, e-mail, or the Internet course forum. The next two scenarios resemble scenario 1, but they allow synchronous on-line communication between the participants and their tutors. The participant should have access to a studio near the place of his/her residence (scenario 2) or acquire a personal computer (scenario 3). The tutor is found at the central studio and he/she can be contacted via an Internet connection at predetermined times according to the course schedule. Apart from the interactive option in scenarios 2 and 3, the students in scenarios 1-3 should be able to:

- have e-access to the course material (found on a web page in the course site),
- communicate (synchronously or asynchronously) with other students and his/her tutor via a specially allocated course forum,
- submit his/her assignments electronically, etc.

A number of courses have nowadays adopted similar schemes, developed on an Internet platform (for instance the on-line quality assessment pilot course at:

<http://mirnix.europace.be/quality/index.php3>).

The last scenario (5) considers the traditional option of attending a conventional university course. This obviously requires that the student reside close to a university that supports the course and find a course time-schedule conforming with his/her professional or personal commitments. Scenario 4 follows the classroom instruction schemes of scenario 5, but the lectures are delivered in situ. Consequently, the tutors have to travel and possibly stay over a period of time at the various remote places where the students reside.

5 COST BENEFIT ANALYSIS

The total annual expenditures are estimated for each one of the five scenarios. The students attending the course are divided into a number of smaller groups that share the same tutors, facilities, etc. The number of persons per group is fixed according to the nature of the student-to-tutor interactions. In the OU scenario, each tutor supervises 30 students, while scenario 5 accommodates up to 25 students in the same university classroom. Note that these numbers are in agreement with common practice in Greek universities. Scenario 4 assumes 20 students on

average. The number is lower than scenario 5, to address the possible difficulty in finding 25 students in each remote site. For the studio-on-line case, one has to account for various practicalities, e.g., that the tutor cannot communicate synchronously with more than 8 students sharing the same studio. The tutor-on-line scenario accommodates up to 15 students per tutor since we do not expect all the students of the group to be logged on at the same time.

Accordingly, each education scheme assumes a different number of hours annually for synchronous student-to-tutor interaction. Based again on common practice, the OU hours are set at 20 though the lectures taking place in scenarios 4 and 5 require 350 hours annually. For scenarios 2 and 3, the number of hours available on line is 300 annually. Since it is up to the student to what extent this availability will be exploited, it is estimated that only 40% of this time will be used.

As an example, Table 4 presents the detailed calculations for the OU option. The total costs per annum consider the depreciation of the original investment (over a period of 3 years), the annual Fixed costs to support the course, and the annual running costs depending on the participants. In terms

of the initial investment, the development of the course material is of crucial importance in a distance course with minimal contact between the student and his/her tutor (Hunt, 1998). According to the scenario, it is possible that this material should be sidelined with software that assists the learning process or enables the on-line communication. The latter, though, does not apply in scenario 1. The annual fixed expenditures relate to the costs of administering and coordinating the course, regardless of the demand. Each student presents an additional expenditure in terms of reproducing the course material, providing personal supervision, etc. However, it is the groups of students one needs to take into consideration when estimating the total course hours per annum. Each hour yields different expenditures according to the nature of the student-to-tutor contact and the facilities required to establish it. According to the scenario, one might include traveling and accommodation expenses or charges for the ISDN line. In addition, the tutors receive a fixed amount per group to cover for the expenses of familiarizing themselves with the course material and/or the way the course is conducted.

Table 4 Total and itemized expenditures for Scenario

	cost (EU)	annual cost (EU/yr)	annual cost per student (EU/yr)
fixed expenditure per course		125,000	694
depreciation time (yrs) = 3			
development of reading material	150,000	50,000	278
administration, in course development	60,000	20,000	111
development of software	45,000	15,000	83
pilot runs	30,000	10,000	56
consultancy	90,000	30,000	167
annual fixed expenditure per course		195,000	1,083
communication	15,000	15,000	83
administration	90,000	90,000	500
academic staff (course coordinators)	60,000	60,000	333
rent of central building	30,000	30,000	167
annual running expenditure per student		121,500	675
reprint of reading material	180	32,400	180
reprint of software	45	8,100	45
administration	150	27,000	150
personal tutor (supervision)	300	54,000	300
hourly running expenditure per group		7,200	40
hours in meetings/year = 20			
rent of meeting place	27	3,240	18
tutor in situ	15	1,800	10
tutor traveling expenses	18	2,160	12
annual running expenditure per group		4,500	25
tutor responsible for group	750	4,500	25
total annual cost		453,200	2,518

Table 5 presents the final and itemized course expenditure estimations for all five scenarios. The best solution is the OU scheme. The studio on line is 60% higher than the best solution, while the option of sending experts in situ leads to more than twice the OU expenditures. Somewhat near the OU is the tutor-on-line alternative, closely followed by the traditional university scheme. If one considers the

practicalities of either moving to a different city to attend a university course, or lacking substantial supervision and tutor support, then scenario 3 probably presents the most attractive alternative seen from the viewpoint of the student. These figures can be reduced if one takes into account subsidies from the government or the European Union (EU) as financial support for postgraduate education.

Table 5. Total and itemized expenditures for the 5 scenarios

	scenario 1 (EU/yr)	scenario 2 (EU/yr)	scenario 3 (EWyε)	scenario 4	scenario 5 (EV/yr)
FIXED EXPENDITURE	125,000	184,400	160,250	81,000	129,000
course development	125,000	155,000	155,000	81,000	129,000
development of reading material	50,000	50,000	50,000	24,000	24,000
administration, in development	20,000	20,000	20,000	20,000	12,000
development of software	15,000	45,000	45,000	9,000	9,000
pilot runs	10,000	10,000	10,000	10,000	10,000
consultancy	30,000	30,000	30,000	18,000	14,000
facilities	0	0	0	0	60,000
remote studios	0	19,200	0	0	0
studio equipment (4 PC's, printers, peripherals)	0	17,500	0	0	0
studio facilities (furniture, carpet, lighting, etc)	0	1,700	0	0	0
central studio	0	10,200	5,250	0	0
studio equipment (6 PC's, printers, peripherals)	0	9,300	4,800	0	0
studio facilities (furniture, carpet, lighting, etc)	0	900	450	0	0
ANNUAL FIXED EXPENDITURE	195,000	249,000	249,000	195,000	186,000
communication	15,000	15,000	15,000	15,000	6,000
administration	90,000	90,000	90,000	90,000	90,000
academic staff (coordinators)	60,000	60,000	60,000	60,000	60,000
rent of central building	30,000	30,000	30,000	30,000	30,000
technical support (central studio)	0	54,000	54,000	0	0
ANNUAL RUNNING EXPENDITURE	133,200	286,875	139,680	573,750	248,625
students	121,500	102,600	102,600	64,800	48,600
reprint of reading material	32,400	32,400	32,400	16,200	16,200
reprint of software	8,100	16,200	16,200	5,400	5,400
administration	27,000	27,000	27,000	43,200	27,000
personal tutor (supervision)	54,000	27,000	27,000	0	0
meetings	7,200	153,900	28,080	388,800	194,400
tutor on line	0	40,500	21,600	0	0
ISDN call charges	0	24300	6480	0	0
anchor person at remote studio	0	40500	0	0	0
technician at remote studio	0	48600	0	0	0
rent of meeting place	3,240	0	0	87480	72900
tutor in situ	1,800	0	0	243000	121500
tutor traveling expenses	2,160	0	0	58320	0
groups	4,500	30,375	9,000	120,150	5,625
tutor accommodation & maintainance	0	0	0	113,400	0
tutor responsible for group	4,500	16,875	9,000	6,750	5,625
remote studio rent and mise expences	0	13500	0	0	0
TOTAL ANNUAL EXPENDITURE	453,200	720,275	548,930	849,750	563,625

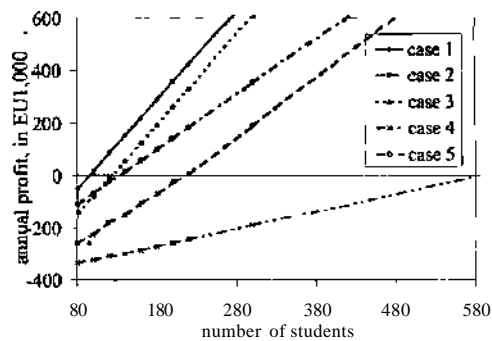


Figure 1. Break-even point analysis on the number of students.

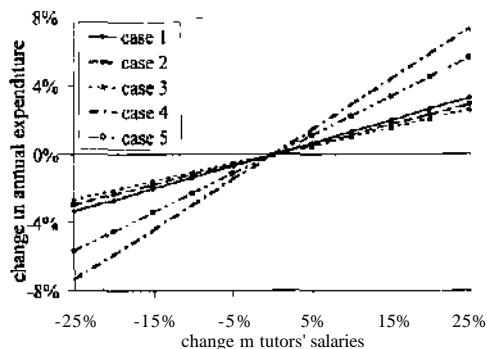


Figure 2. Sensitivity analysis on the expenditure for tutors.

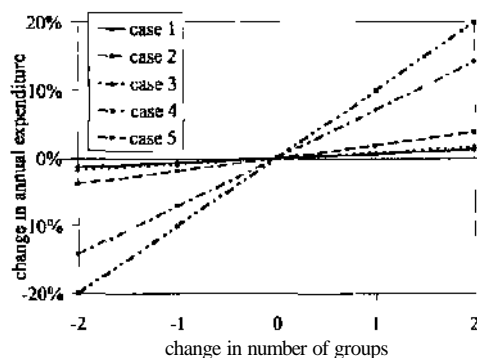


Figure 3 Sensitivity analysis on the number of groups.

6 BREAK-EVEN POINT AND SENSITIVITY ANALYSIS

The previous sections discussed the results of the economic/technical analysis in terms of - the expenditures, without considering the revenue resulting from the tuition fees paid by the students.

A fixed fees platform of EU4,500 is assumed for all the scenarios, leading to EU3,000 annually per student.

Based on the fees, the number of participants is varied so as to identify the break-even points for each scenario. The results are shown in Figure 1. Scenarios 1, 3 and 5 present reasonable break-even points at 95, 123, and 131 participants, respectively. Scenarios 2 and 5 present break-even points at 215 and 587 participants, respectively. The last numbers are way off the course analysis and design standards, rendering the respective scenarios unfeasible (at least without some sort of financial or other support). Of the feasible cases, scenario 1 is always the most economical regardless of the number of participants. With the expected demand of 120 students, scenarios 3 and 5 appear economically unfeasible. However, the EU allocates special budgets to the financial support of distance education courses, and thus the expenditures for scenarios 1-3 can be reduced.

Figures 2 and 3 illustrate results from the sensitivity analysis. The former considers changes in the salary of the tutors and how these affect the total annual expenditures. Note that the tutors are temporary staff with annual contracts and their number follows the course demand fluctuations. With respect to Table 5, the costs appearing in the tutors' salary refer to the supervision of students and groups, and in-situ or on-line hourly meetings. Clearly, an increase in the tutors' salaries brings an increase in the overall annual costs, but the extent of the change differs for each scenario. The slope is similar for the first three scenarios, i.e., the distance education alternatives. Scenarios 4 and 5, however, require many hours of lecturing in situ, and this increases the contribution of the tutor salary to the total expenses.

A similar trend can be seen in Figure 3. By increasing the number of groups, we impose an incremental change in the total annual expenditures. Again, the extent of the change depends on the scenario, with scenarios 5 and 4 being the most affected. However, the distance learning schemes are insensitive to the number of groups of students. Consider scenario 1: if we increase the groups from 4 (base case, assuming 30 students per group) to 6 (i.e., by 50%), the overall cost increases by less than 3%. Similarly, in scenario 2, an increase of 25% in the groups (from 8 to 10) results in an additional 2% in the annual costs. This is an important observation, since the number of groups can indeed vary based on course demand in the local communities.

7 DISCUSSION AND CONCLUSIONS

This paper presented a study of possible education schemes for mining as well as other engineers

working in mining sites in Greece. Because of the nature of their job, they usually reside in remote areas scattered across relatively inaccessible rural regions. The location issue, along with the wish of these professionals to pursue postgraduate degrees, makes them an ideal target group for DL courses.

Using a modified three-stage Delphi approach, a course often modules is proposed. In the last stage, a survey is conducted with two samples, one of mining engineers, and another of chemical engineers, metallurgists and industrial chemists working in mining sites. The survey has proved that there is a high statistical agreement between the samples as regards the demands for educational services. As a result, the suggested course applies to a wider market, with an estimated demand of 120 participants annually.

Five different course implementation scenarios are considered in order to examine the economic viability of the course. The scenarios include traditional in-situ classroom instruction schemes as well as DL alternatives. The former appear as reference cases, while the case of full-time attendance in a university is obviously in conflict with the professional commitments of mine employees. The other options include conventional and on-line DL. The on-line schemes include synchronous interaction with the course tutor through an Internet connection. The conventional and the tutor-on-line schemes are economically feasible over the break-even point and sensitivity analyses carried out here. If criteria other than the cost are considered, the tutor-on-line option appears more promising, since it provides the opportunity for further communication between the student and his/her tutor on a synchronous, visual and vocal basis.

It is further suggested that the implementation is carried out mainly by the Department of Mining & Metallurgy Engineering of NITJA. In effect, NTUA has a suitable infrastructure to support continuous (as well as under- and postgraduate) education, while open universities avoid issuing degrees in chartered professions (e.g., in law, medicine, and

engineering). The above scheme will also include as board members/consultants the Union of Hellenic Industries, the Ministry of Industry, Energy and Technology, and the Technical Chamber of Greece, as well as HOU.

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