A Concept for Minerals Engineering Education and Research in Cooperation with Industry

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Abstract — This paper presents a concept for training mining/minerals engineers in cooperation with the industry combining the age-old and digital-age concepts. The students, after first two years in a college for the foundation/basic courses, will be centered in the industry, rather than at an academic institution, where minerals engineering coursework will be offered in structured or self-paced learning formats through the internet. The concept has several advantages, including: 1) Industry hiring local area students who have the potential to be long-term employees; 2) Industry’s immediate access to employees with developing engineering skills; 3) On-the-job training while going through school, thus reducing industry training costs after graduation; 4) More effective learning through observing complex operations at operating mines; 5) Students and industry input for continuous improvement of the curriculum; 6) Greater amenability on the part of industry to actively participate in research and development since faculty will be more attuned to industry needs; and 7) Increase in the flow of real research problems for graduate students. Finally, the implications for student quality, accreditation, assessment of partnership, academic freedom, and fundraising for scholarship and research are discussed briefly.

Index Terms — Minerals education, industry co-operation

INTRODUCTION

The number of academic programs offering degree in minerals/mining engineering has been significantly decreased worldwide due to lack of critical student mass and high cost of education. Although consolidation in the industry and availability of software for engineering problem-solving has permitted the industry to work with fewer engineers over the past several years, the mining industry is currently experiencing significant shortage of trained mining/minerals engineers. Often, the university administration looks at mining/minerals program as non-critical, and during budget crisis, decide to merge/eliminate these programs with other large programs to develop cost savings.

In this paper, authors present a new concept for minerals education utilizing the high technology distant learning in cooperation with the industry. This will ensure that the flow of mining graduates continues. The following sections include a brief description of the current education practices, development of high-quality self-paced courses, providing academic advising through video-conferencing, e-mail, telephone, or personal visits and the associated advantages and disadvantages/concerns. A plan to provide laboratory training and design experience at mine sites in a real-life setting, industrial or government laboratories, or at the academic institution, perhaps with a residency requirement of one semester, is presented.

BACKGROUND – DESCRIPTION OF CURRENT PRACTICE

An overview of the typical current practice is shown in Figure 1. Students enter a senior academic institution (university) after high school or after obtaining an associate degree in science from a community college. During the first two years, a student focuses on fundamentals of science and mathematics, with little or no mining related coursework or field internships. Engineering Science and mining related coursework are emphasized during the junior and senior years. The students also work as summer interns in industry. The outcomes of this practice, for graduates, industry, and academic departments are as follows:

Graduates
- An average student requires about 4.8 years to graduate - typical of engineering graduates.
- Less than 30% of the coursework is directly related to mining industries.
- A typical student spends no more than 6-months as an intern in mining industry. Of this, no more than 25% is spent in the face area (~ 1.4 mm). Most students work as helpers in surveying, construction, belt cleaners, quality control, and special projects earning $ 10-15/hour.
- Most graduates learn about mining operations on-the-job after graduation.
- There is limited ability to take electives and to specialize in different mining industries (coal, aggregate, etc.) since
curricula are very structured to meet the accreditation (ABET) requirements, and academic unit resource constraints (limited faculty).

- Students generally have to work part-time (50%) at low minimum wage to earn money to pay for school.

Industry and Academic Departments

- Industry spends considerable time recruiting summer interns and full-time graduates. In addition, they maintain on-the-job training programs for graduates to nurture them to fit within their organization.
- Academic departments spend a large amount of time in student recruitment, retention, and working with industry for scholarships. At least 10-15% of faculty time and 50% of the department chair’s time is spent on these activities. That is equivalent to at least one full-time faculty allocation in a typical 5-person department in the United States.
- Since industry is understaffed, academic departments have to work very hard to seek industry input on curriculum and performance of summer interns and graduates.

Most of these disadvantages for different constituencies could be overcome through an academic program that centers the students in industry during the last two years rather than at an academic institution. An example of such programs in the past is the well known cooperative programs (COOP) in mining education that involved students working for one semester and then returning to school for coursework for one semester. The quality of graduates and industry satisfaction from such cooperative programs was high. The academic units were able to run such programs efficiently and economically because student enrollments were high. In these programs, the students had to return to school for coursework because distance learning was not available.

As discussed earlier, the current environment for mining education is very different. On the one hand, student enrollments and number of graduates per year, in most mining departments in the US are small, 20-30 and 4-5, respectively. The academic units are not well funded and have inadequate well trained faculty to run the programs. On the other hand, mining and related industries will be demanding well trained graduates over the next decade since these industries have not hired graduates over the last 10-15 years to account for aging workforce and future needs. Therefore, there is a need to develop academic programs that allows industry to utilize workforce-in-training immediately, and are economic to run by the university with limited well-trained faculty. The authors have developed such a program concept utilizing both the age-old concept of COOP and digital age concepts of distance learning. The authors call it cooperative program of the 21st century or COOP21.

**PROPOSED EDUCATION CONCEPT FOR MINING ENGINEERS (COOP21)**

The overall concept of the proposed plan is shown in Figure 2. Some of the salient program characteristics are summarized below. Additional details may be developed by the academic units offering such programs as the program evolves.

- A student completes an Associate Degree in Science from a community college, or two years of pre-engineering from a 4-year college.
- Work-study enterprises (WSE) sponsor scholarships to benefit employee children and others to pursue a mining engineering degree. A WSE may include mining industry, utility, equipment manufacturer, government agency, etc.
- A 4-year academic department interfaces with different WSE to coordinate student placement to work part-time (50-75%) while pursuing a BS Degree. A WSE may offer scholarships each semester to provide opportunity to different individuals to find the best match for their organization.
- Faculty develops mining related courses that are taught on-campus and/or off-site (depending upon enrollment) using digital age concepts (distance learning, web site, self-paced learning, problem-based learning, etc). Laboratory training is provided through on-campus, virtual, or in-mine laboratories or a combination thereof as appropriate. A capstone project is developed in concert with academic faculty and industry professionals. All Accreditation Board for Engineering and Technology (ABET) requirements of the EC2000 are met. Most of the elements of distance learning required here have already been developed and are being used in other engineering disciplines.
- Students may choose to learn course materials through any or all of the concepts above depending upon their work schedule, and flexible study time allocated by the WSE.
- Topics learned through coursework are supplemented through student experience in a field setting.
- Students are assessed by instructors and industry professionals similar to any distance learning class.
- The WSE may give some flexibility to students to see different mining-related operations beyond their work assignments.
- Academic units may interface with a near-by community college for contacts with students in that area, provide one-to-one education, provide laboratory training, etc.
• Students interface with instructors through web, e-mail, or telephone calls during office hours maintained by instructors.
• Student advisement is done through email, web, or in person.

ADVANTAGES OF THE COOP21 CONCEPT

The authors believe that the proposed concept has advantages for both the students and the industry. Specific advantages for the students are as follows:
• Flexibility of curriculum allows students to specialize to a degree in different types of mining through placement in different WSE – aggregate, coal, non-coal operations. The students also have some choice of electives.
• Students learn state-of-art computer software in use at the industrial site.
• Students learn from instructors and professionals simultaneously.
• Career choices can be made with knowledge of the work environment and job expectations.
• On-the-job training starts early. Therefore, potential for rapid professional growth is high.
• Supplement book knowledge with learning and training in real-life environment.
• Students and industry professionals provide real life practical examples and data that can be incorporated into course materials.
• Students learn from instructional course materials with immediate supplemental education and training in real-life settings.
• Students earn good money while going to school. This should also attract some non-traditional students to enter school.

From the industry’s perspective, the following advantages are obvious:
• Most students will come from the regions near mining areas. Therefore, long-term potential for employee retention is very high.
• Work-study incentives for employee children at mines should provide a strong recruitment tool for good quality students to pursue degrees in mining as well as other engineering disciplines.
• Should some work-study students choose not to pursue engineering degrees, they may still have potential to be employed in maintenance, or as superintendents, assistants to superintendents, surveyors, or in charge of special projects. Such educated professionals will be assets to the industry in the long run.
• Industry will have immediate access to educated professionals on the move with long-term employment potential within a company.
• Students work on real-life problems and projects.
• Industry continuously provides input on curriculum and course content.
• Work-study incentives for employee and non-employee children provides good public relations and employee morale.
• Economic potential around mining areas is increased because of young educated professionals.
• Industry has the ability to influence curriculum and course content.

The academic units will have the following advantages:
• Increased student placement rate for community college graduates.
• With limited faculty, units can effectively prepare professionals for different mining industries – coal, aggregate, non-coal, etc.
• Significant increase in off-site enrolled students.
• Continuous feedback from students and industry professionals on coursework.
• No energies are expended on seeking scholarship support, recruitment, and placement in summer and full-time jobs. These energies can be expended in research and continuing education activities.
• Faculty benefits from strong relationships with industry.
• Faculty may get research/consulting projects because of close relationships with industry.
• Faculty works on cutting-edge technologies and problems.

ROLES AND RESPONSIBILITIES FOR DIFFERENT CONSTITUENTS: SOME PRELIMINARY THOUGHTS

Figure 2 shows community colleges, industry, and the academic unit at a university working cooperatively to make such a program a success. Below is a summary of suggested roles for each constituent and interactions among them. These are not cast in concrete and must be developed by the constituents working cooperatively.

University (A)
• Has the overall responsibility for administration and academic requirements of the program and coordinates student placement in WSE. Will be responsible for student advisement, retention, and progress to graduation.
• Interfaces with two-year programs for WSE requirements. Advise curriculum revision for two-year programs based on ABET requirements and input from WSE.

Two-Year Program (B)
• Has the overall responsibility for administration and academic requirements of the 2-year program. Responsible for student advisement, retention, and progress to graduation.
• Responsible for advertising the WSE requirements to potential students.
• Assists with curriculum development at the University (A).
• Provides facilities for WSE students-faculty interactions.

Work-Study Enterprise (C)
• Provides work-study scholarships with a healthy environment for student learning.
• Assists with recruitment, retention, and placement efforts.
• Guides coursework development and offerings.
• Provides student and faculty assessment.
• Identifies needs for education and training during Year 1 and Year 2.
• Provides a platform for faculty experience in various work-study enterprises.

INITIAL PROGRAM IMPLEMENTATION: SOME THOUGHTS

Selected ABET representatives will be consulted prior to implementing the concept. An approval for implementing a ‘pilot program’ may be sought. It is proposed to implement the program initially with some structure during the evolutionary phase, while maintaining the flexibility inherent in the concept. For example, coursework may be set up to accomplish learning of certain amount of material for each week with homework, laboratory report requirements and a quiz. Number of examinations may be increased from three to four each semester to ensure timely learning of material. A WSE contact may be asked to give oral examination each month on the material learned in cooperation with the instructor. A comprehensive examination of 6-8 hours each year may be required to ensure in-depth learning of coursework. The merits of some of these thoughts will be evaluated during pilot scale programs currently being conceived. The Society for Mining, Metallurgy, and Exploration, Inc., may be involved in the development of distance learning coursework so that membership feedback and peer-review is an integral part of the course development.

EC2000 ANALYSIS

It is generally accepted that an undergraduate program in engineering is of any value only if it is accredited by the ABET. Over the last few years, there have been significant changes in the program criteria for engineering programs as well as program evaluation. ABET has provided the programs with more flexibility in setting their own goals and objectives, and developing curriculum that ensures that the objectives are met appropriately. When the program objectives appear not to be satisfied, the program faculty is required to take steps to ensure that appropriate changes are made within a reasonable period following a well documented process. Furthermore, it requires feedback at all levels to ensure continuous improvement and meeting of goals and objectives. COOP21 allows such feedback without much effort.

For the proposed program, the objectives of the program will be set to include distant learning with proper guidance and direction by the faculty and industry mentors. During the initial trial period, changes will be made to fine-tune the program goals and objectives to ensure that the ABET requirements are met in full.

For accreditation as a mining/mineral engineering program, the ABET criteria can be divided in to three parts:

1. The graduating students must have the ability to apply mathematics through differential equations, calculus-based physics, general chemistry, and probability and statistics as applied to mining engineering problems applications; fundamental knowledge in the geological sciences including characterization of mineral deposits, physical geology, structural or engineering geology, and mineral and rock identification and properties; proficiency in statics, dynamics, strength of materials, fluid mechanics, thermodynamics, and electrical circuits.

2. The graduates must demonstrate proficiency in engineering topics related to both surface and underground mining, including: mining methods, planning and design, ground control and rock mechanics, health and safety, environmental issues, and ventilation; proficiency in additional engineering topics such as rock fragmentation, materials handling.
mineral or coal processing, mine surveying, and valuation and resource/reserve estimation as appropriate to the program objectives.

3. The curriculum must have laboratory experience leading to proficiency in geologic concepts, rock mechanics, mine ventilation, and other topics appropriate to the program objectives.

The program proposed in this presentation satisfies all of the above three requirements. The first one is met during the first two years when the students are taking core courses. The second component is satisfied when the students take courses through distant learning. Each one of the topics listed by ABET will be covered in one or more courses. Finally, the laboratory component will be satisfied in one of two ways. Virtual laboratory classes will be developed for these topics unless the students have an opportunity to obtain hands-on experience in a particular area. For example, a student working in an underground mine can easily be exposed to the instrumentation and application in the area of mine ventilation by working with the ventilation engineer for a couple of days. In fact, the authors believe that such an exposure would be superior to a typical laboratory class in an academic environment. Finally, prior to implementing the proposed program, ABET members will be consulted informally and their opinion sought.

STUDENT AND INDUSTRY FEEDBACK

After developing an outline of the proposed program, undergraduate and graduate students were contacted to obtain their input. The students were given a questionnaire to complete after the presentation. To gauge the industry reaction, the plan outline was also presented at the last annual meeting of the Industrial Advisory Board of the Mining and Mineral Resources Engineering Department at Southern Illinois University. The comments received are summarized below:

Students:
- The proposed program will reduce the financial burden of students and families.
- Ideally, 50%, and no more than 75%, should be set as the maximum time at the WSE to leave sufficient time for academics.
- The students will be more employable after graduation after the ‘real world’ experience.
- The program gives more flexibility to students.
- The obvious concern was the lack of interaction with instructors and academic supervision.

Industry:
- In general, most industry representatives were impressed with the concept.
- There was a concern that this might lead to demise of the traditional programs and that can be dangerous.
- The main concern expressed by the industry group was that it might be difficult to get rid of a student if the match between the student and industry was not the best.
- The final concern was that the students would be counted as employees since they will be on the company’s payroll. This will not be looked at favorably by the management when a ‘head count’ is done. The suggestion was that the students not be employees of the company. Rather, they should maintain their student status with a scholarship from the company.

The third comment is a non-issue since a WSE will offer internships for one semester at a time. The authors are currently working with Human Resources groups from different mines to discuss the last concern.

FUTURE PLANS

Based on input to date from industrial advisory board and the currently enrolled students, it is planned to evolve this concept further with additional discussion and input from university administration, faculty, ABET, industry, and alumni. Faculty and student acceptance of the concept is most critical at this time to chalk plans for its future. A National Science Foundation proposal for development of coursework for distance learning and its implementation on a pilot scale is being considered. A steering committee consisting of all constituents will be an integral part of such a pilot program. Assessment strategies and tools, an integral part of the EC2000, are being conceived at this time for discussion of the concept with ABET.

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FIGURES AND TABLES

FIGURE 1
TYPICAL CURRENT PRACTICE FOR EDUCATING MINING ENGINEERS

![Diagram showing typical current practice for educating mining engineers]

- Fundamentals: Sciences and Math
- Social Sciences
- Communication Skills
- Very little engineering science

Year 1

Year 2

Foundation Courses in Mining Engr. (12 SH)

Year 3

Year 4

Environmental Issues

Capstone project

Summer work in non-mining environment

Internship in mining Industry

FIGURE 2
AN OVERVIEW OF THE PROPOSED EDUCATION CONCEPT COOP21

![Diagram showing the proposed education concept COOP21]

ABET

4-Year Academic Degree Unit

Advisory Board

Work-study Enterprise

- Mining Company
- Utility Company
- Construction Company
- Equipment Manufacturer
- Government Agency

2-Year Community College

4-Year College

A-B

C-A

B

C

Year 1

Year 2

C - B

A