Introducing Teachers to Engineering Practice

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Abstract

Michigan Technological University has developed a new Master of Science in Applied Science Education for inservice teachers. As part of this program, teachers will be required to complete a 12-credit applied science core focusing on real-life engineering applications of math and science. The first of the courses from this core, The Engineering Process, was offered during the summer of 2001 on Michigan Tech's campus. The purpose of the course was to familiarize inservice secondary math and science teachers with an overall view of engineering and to the methodology and implications of the engineering process. This course was delivered in an intensive two week long (ten day) format and drew upon the talents of several faculty from many different areas within the College of Engineering and the School of Technology. Students were exposed to many different disciplines as faculty explained the societal, economic and technological significance of key areas of their fields of expertise. The students designed, analyzed, constructed and tested truss bridges made from file folders according to specifications provided by the instructors. Finally, each student was directed to develop a teaching unit that integrates some of the concepts of scientific inquiry and application discussed in the course into their 7-12 teaching. This paper describes our Masters program, provides an outline of the course titled "The Engineering Process," and presents results from our first offering of the course.

Introduction

The precollege education system in America is currently under pressure to adopt standards-based curricula. Outcome assessment of learning is of paramount importance in this new educational climate. Nearly all of the national standards in math, science and technology include standards related to the inclusion of "real-life" applications of material[1-3], however, many teachers are at a loss to provide these types of everyday examples in their classes. Further, we have found that many secondary teachers do not have an informed idea of what engineering is all about, and therefore, they can not easily advise their students to pursue an engineering career. To combat these twin problems, at Michigan Tech we have developed an innovative degree program--the Master of Science in Applied Science Education (MS-ASE). Through the coursework in this program, inservice teachers will be able to develop a clear understanding of the engineering profession and will experience firsthand how engineers apply math and science principles in the solution of real-life problems. We believe that through this program, not only will secondary math and science instruction improve for affected students, but also we will develop a cadre of teachers who understand engineering and who encourage their students to pursue engineering careers.

The MS-ASE Program

The Master of Science in Applied Science Education (MS-ASE) degree is intended to be a graduate degree for inservice secondary mathematics and science teachers that promotes professional development within their disciplines and addresses their classroom and students' needs. Through their coursework, these candidates must demonstrate advanced ability to integrate engineering and other real world applications into the mathematics and science curriculum serving students in grades 7-12. This emphasis is a priority in both state and national standards for secondary mathematics and science education.

In the state of Michigan, new secondary teachers are awarded provisional certification for five years. During that five year period, teachers are required to complete either an 18 hour approved program of study or a master's degree to move from provisional certification to professional certification. Most new teachers, as they work toward their professional certification, simultaneously seek enrollment in a master's degree program in education. There are financial and career benefits of the master's degree that surpass those of just professional certification. This program is designed to meet the needs of inservice teachers, primarily in their first five years of teaching.

The MS-ASE degree program consists of the following:

- Engineering Core (12 credits)
- Education Core (6 credits)
- Education Research Report (2 credits)
- Industry Internship (3-6 credits)
- Math/Science/Education Electives (6-9 credits)

The engineering core consists of three courses, ENG5100-The Engineering Process, ENG5200-Engineering Applications in the Physical Sciences, and ENG5300-Engineering Applications in the Earth Sciences. Each of the classes in the engineering core takes place as a two-week intensive in the summer. The education core consists of three 2-credit courses offered via the Internet during the academic year. The industry internship will take place during one or two summer months. In their internship, teachers will work alongside engineers in a local industry/governmental agency over the intended timeframe and will then write a report and teaching unit describing their experiences. Of the elective courses, at least one course must be in the area of applied life sciences, since state and national science education standards are grouped according to life, physical, and earth sciences, and since engineering disciplines available at Michigan Tech do not generaly emphasize applications in the life sciences.

The Engineering Process Course

Of the three courses in the engineering core, ENG5100 was offered during the summer of 2001 and the remaining two courses will be offered during July and August of 2002. This paper will focus on describing this first course and will present results from its first offering. The focus of the first course was primarily on the engineering process as applied to Civil Engineering and Mechanical Engineering to some degree. The remaining two courses that students in this program will take will focus more on the application of the engineering process to other engineering disciplines (Electrical, Computer, Chemical, Materials, etc.). An outline of the course schedule is shown in Figure 1.

Week 1:

Monday	Tuesday	Wednesday	Thursday	Friday
Introduction to the course and to the program, Pre-testing	Introduction to Spatial Visualization, Graphics, and Engineering Drawings	LEGO project-- Phase II	Mechanics of Materials and Truss Analysis	Project Scheduling
Engineering history, profession, and disciplines	LEGO project-- Phase I	Basic Statics and Mechanics of Materials	Guest Speaker Design Project Assigned	Engineering Econ and discussion of the non-technical influences in engineering design

Week 2:

Monday	Tuesday	Wednesday	Thursday	Friday
Calculating Volumes and Quantities, Project Estimating	Geological, Mining, and Environmental Engineering Applications	Design for Manufacturing	Electrical Engineering Application	Design Project Presentations
Discussion of bidding process and field trip to construction site	Field trip to local Mine	3-D Computer Aided Design	Design Project Testing	Course wrap-up and final assignment, Post-testing

Figure 1. Then Engineering Process Course Outline

There were two projects that students completed during this session to allow them to experience the engineering process firsthand. (Please note that the "students" referred to in the following sections were the 7-12 teachers enrolled in the Engineering Process Course.) The first of these projects involved the use of LEGOs and was conducted as follows. On Tuesday afternoon of the first week of the class, students were divided into teams and were told that they were all “Owners.” As Owners, they were to describe in writing a project that they would like to have constructed out of LEGOs that would perform a function and involved a golf ball in addition to the LEGOs, however, they were not given any LEGOs to assist them in the development of these project descriptions. Student groups then gave their project specifications to a different team. Students were now told that they were “Engineers” and that they should develop a set of drawings and specifications for the project detailed in the owner project descriptions. Engineering teams worked on these drawings and specifications during the evening and brought their completed construction documents to class on Wednesday morning. Students once again exchanged documents with another team and now all teams were told that they were “Contractors.” Their job was to use the plans given to them by the engineers, develop a cost estimate based on unit prices for LEGOs, procure the materials required to construct the project, and then to build it as the engineers and owners looked on. The teacher acted as the supplier and

Contractor teams were sometimes chagrined to find out that yellow LEGOs were sold in lots of five not three, etc. After construction of all projects, class discussion followed.

The second project that students completed involved the design, construction and testing of a truss bridge made of manila file folders. Students were each given a copy of "Designing and Building File-Folder Bridges[4]," which outlines this type of project. Bridge geometric parameters as well as load conditions were modified from those presented in this text so that students would gain the feel of a true "open-ended" design project. Student teams worked intensively on this project over a week-long period. On Thursday of the second week of the course, student bridges were tested to determine their ability to resist the specified load. Students then made PowerPoint presentations regarding their design projects and the results from the load testing on Friday of the second week. Student teams were also required to submit design reports complete with sketches and truss force/stress calculations.

Informal Student Feedback

The students were exposed to eight Michigan Tech faculty and a wide range of topics in a short period of time. This format approached a sensible capacity for the students since much of the material discussed was new to them. Some individuals tended to express concern over the rigor of the material and had difficulty relating the presented concepts to their own instructional purview. Other students were pleased with the exposure to these ideas and could easily see how they might them integrate into curricula at their schools. In informal class discussions, students expressed the following desires/concerns:

- Since they were only on campus for a short period of time, many of them would have liked to have had the opportunity to meet other graduate students so that they would feel more like a part of the Michigan Tech student body. They had a lot of interactions amongst themselves, but little or no contact with other students on campus, and therefore, they did not feel "connected" to the university.
- There was a great deal of frustration expressed regarding the fact that there were no faculty around over the week-end to help them when they had problems regarding their design project calculations. Engineering instructors quickly realized through these discussions that problems that may seem trivial to the average engineering student were difficult to comprehend for these students. The frustration the students experienced and their overall lack of confidence in their ability to solve these problems resulted in a great deal of anxiety and angst exhibited by the participants.
- Students were not prepared for the level of time commitment required of them during the course. Many of the students had participated in previous professional development workshops offered by Michigan Tech and were astonished that we would actually be requiring them to work evenings and over the week-end. Previous teacher workshops at Michigan Tech were merely 8-5 propositions. In fact, one student had to drop out of the program because she had committed to teaching an athletic camp during the evenings that the course was taking place.

- Students also thought that while the design project was beneficial, there was too much time spent on menial tasks, such as cutting and folding members to sizes, that were not educationally beneficial to them.

Results of Pre-/Post-Testing and Surveys

Instructors of the various sessions of the courses were asked to provide question pairs for pre- and post-testing that were applicable to the material they intended to present. These question pairs were divided into two separate exams. Half of the students completed Exam A as a pre-test and the other half completed Exam B as their pre-test. At the end of the two-week session, students were given the opposite exam as a post-test. Test items included general questions regarding the engineering profession as well as questions about specific applications they had worked on during the course. For example, there were questions where students were given a simple truss and asked to compute the loads in members and reaction forces, or to identify any zero-force members present. It was found that students scored significantly higher on the post-test (average=19.5/21) than they had on the pre-test (average score=9/23) and the gain was statistically significant ($p<0.001$).

In addition, students were given an attitudinal survey both pre- and post-course. The following were the results from this survey:

- There was significant increase in enthusiasm for teaching through participation in the course.
- There was a significant increase in the amount of support that the students felt from other members of the educational community. The group activities seemed to have facilitated this change.
- Some of the student misconceptions about the accessibility of engineering principles, the content of the discipline and applications of engineering were dispelled.
- There was no change in the students' confidence in the ability to perform engineering-related tasks or activities.
- Students reported that the material was too difficult and they felt it required more of a background in engineering in order to be successful.
- Students found that the course was not well organized and that smoother transitions between topics would be beneficial.
- Students stated that there should have been a faculty member or TA available to them as they worked on their assignments.

Changes Planned for 2002

As a result of the post-course survey and in-class feedback from the students, changes are planned for the next offering of the course. A faculty member will coordinate the course and be readily accessible to the students for the duration of the course. Some of the content will change in an attempt to make better connections with the students typical educational background. Most of the students in this course taught math, physics, and chemistry so more emphasis will be placed on applications that illustrate those fundamentals. Our lecturers will return the following day to answer questions or give support for any homework that may have been assigned. The students will be toured through various research laboratories at the university where they will meet graduate students in various engineering and science disciplines. This, it is hoped, will help them broaden their view of the field and to meet fellow students engaged in research. There will also be an evening activity that will afford our students the opportunity to get to know some of these engineering graduate students on a personal level. To better facilitate the integration of the presented materials, a web page has been created that outlines several explorations and cross references standards. In addition, we will hire undergraduate and/or graduate engineering students and make them available during the evenings and on the week-end to help validate calculations and assist in the construction of student projects. In addition, the schedule for the second week of the course has been modified as shown in Figure 2.

Week 2:

Monday	Tuesday	Wednesday	Thursday	Friday
Calculating Volumes and Quantities, Project Estimating	Design for Manufacturing	Mechanical Engineering Exploration	Applied CAD and CAE	Project Presentations
Discussion of bidding process and field trip to construction site	Manufacturing Simulation Lab	CAD Dynamics Lab	Design Project Proof Load Test	Final Assignment

Figure 2. Revised Schedule for Week 2 of Engineering Process Course

An interesting benefit of the course has been a collegiality that has formed between some of the students and faculty. Students a year later are contacting faculty to discuss ideas about integration and expressing a genuine interest in substantive dialogue. This suggests that as the program matures, so will this relationship.

Conclusions

This course is still a work in progress. The faculty are learning a lot about the world our secondary teachers work in, and our students are learning a lot about engineering. As this process continues the course will change to better capitalize existing technologies and focused content. As more students come through this course, the network of secondary teachers with common interests will grow. Our web presence will help these teachers to collaborate and share classroom experiences with the faculty at Michigan Tech and each other.

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