Developing an Outreach Program to Introduce Engineering to Non-Engineers

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Abstract

We live in a high-technology world where many people do not understand the things they are using, let alone the implications of the technology they are using. It is in the engineers best interests to work to improve the technology literacy of society.

The have been involved with such outreach in several ways. One way to improve the technology literacy of our society is to improve the technology literacy of future teachers. To work toward that end, we have created a course for education majors with the title: *Problem Solving in Engineering Science for Future Teachers*. This course is aimed at sophomore level education majors and counts as a physical science course in most of their curricula. The authors co-teach this course with an education professor so that we can model good teaching as well as good content. Many active learning techniques are used in this course. This course is a mixture of laboratory and lecture. It meets in two hour long class periods so we can do the labs in the class itself. We will be teaching this course for the third time in spring 2002. This course is part of a much larger program sponsored by NASA called Project NOVA. The goal of Project NOVA is to improve the math and science education of K-12 students by improving the math and science education of future teachers. The Louisiana Tech group is one of the few in this project that are working in the area of engineering.

Through the things that have been learned in teaching this course, the authors have reached out to other groups as well. Our students have put on workshops for in-service teachers in our region, demonstrating the hands-on science skills that they have learned in this class. This helps make a difference in class rooms of current teachers. The first author did a presentation at the state science teacher's association meeting to introduce more in-service teachers to what we have done.

The authors have also had our students make presentations using simple physical science experiments in local fourth-grade science classes. This helped have an impact on current teachers, as they observed what could be done. It also helped to have an impact on elementary school children who now have a very different attitude to science and engineering.

Creating a Class Where Outreach is a Key Component

Background for Our Course

The main mechanism for this outreach program has been the creation of a new course, which has the title: *Problem Solving in Engineering Science for Future Teachers*. We will first describe how this course has been developed, and then discuss the content of the course.

The health of science and engineering tomorrow depends on improved mathematics and science preparation and problem-solving skills of our students today. One cannot expect world-class learning of science, mathematics, and problem solving techniques by students if U.S. teachers lack the confidence, enthusiasm, and knowledge to deliver world-class instruction[1]. One way to improve K-12 science education is to improve current knowledge and preparation of the future teachers themselves.

Louisiana Tech University's undergraduate engineering program has been significantly modified during the past four years. Emphasis has been placed on creating an integrated (college-wide) program for freshmen and sophomores. A key part of this program is a three-course sequence in the freshman year that largely deals with engineering problem-solving.

It is our belief that part of the problem with K-12 science education is that teachers do not know how to relate the science they are teaching to real-world experiences. We have incorporated what we have learned in developing our freshman engineering course sequence as a basis to create a new three-hour course in engineering problem-solving. This course is specifically designed for education majors. They are shown how to solve real-world engineering problems and how to teach such subject matter to their own future students. In this course we model innovative teaching techniques as well as provide mathematics, science, engineering, technological and problem-solving experiences for the students.

This course provides an exciting, motivational learning environment in which students perceive the world's underlying science and mathematics principles that promote an understanding of the physical world. This is done within the context of a collaborative learning environment. Students enrolled in this course are instructed and assessed through a hands on/minds-on student-centered constructivist approach. Education majors are immersed in a holistic and interdisciplinary approach to problem solving and application through engineering, science, mathematics, and technology, which they in turn will be able to model for their future students.

Our Course as Part of a Larger Project

Our problem-solving course was created through sponsorship of the NASA *Opportunities for Visionary Academics* (NOVA) program. NOVA was created out of a concern for how universities prepare new teachers. Comprising a network of 76 member institutions, NOVA partners are working to produce enhanced scientific literacy for pre-service teachers. This effort is being accomplished through the demonstration of an undergraduate science and mathematics course framework, examples of successful course models, and a mentoring support system for faculty wishing to implement new courses or modify existing courses at their universities. The framework uses interactive learning and integrates science, mathematics and technology as a means of developing a new paradigm for educating pre-service teachers.

Since this course was created with NASA sponsorship, it is desirable to have a connection to one of NASA's strategic directions. The problem-solving skills can be most effectively taught in the context of solving actual engineering science problems. The unifying theme is "Our Material World." The course examines the physical, mechanical, and chemical behavior of materials. It emphasize how their internal structure affects their behavior. This course interacts with two of NASA's four strategic enterprises: Human Exploration and Development of Space, and Aeronautics Technology. Both of these enterprises have a materials-related problem at their core. In the context of this course we examine a number of specific materials requirements. One example is the desire to use ceramic matrix composite materials in several engine components on the next generation of the Space Shuttle. To increase engine efficiency there is a need to create engines that can run at higher temperatures. This very crucial operating requirement embodies both mechanical and chemical aspects. This is a topic on which one of the authors (Jordan) has directly worked during the summers of 1997 and 1998 as part of the Summer Faculty Fellowship Program at the Marshall Space Flight Center.

Content of Our Course

Problem Solving in Engineering Science for Teachers is an integrative course designed to enhance engineering, science, mathematics, and technology literacy of pre-service teachers through a problem-solving study of matter in our world. The authors of this paper are the engineering instructors for the course.

This course has the following catalog description: "An integrative course to enhance engineering, science, mathematics, and technology literacy of pre-service teachers through a problem-solving study of matter in our world." The course is a three-hour integrated lab/lecture course. In practice it is taught in three 2–hour blocks. This allows us to integrate the labs and lecture. The purpose of the labs is two–fold: it provides students with hands-on experiences in material behavior, and it models for students how they can teach these concepts to their future students. Problem-solving skills as applied to real-world issues dealing with matter and materials are taught. This is an integrative course that utilizes engineering, all science disciplines, mathematics, and technology for creative problem solving as demonstrated through process skills and product outcomes. Attention is paid to apparatus, instructional materials, instructional strategies, NASA's Strategic Enterprises resources, and laboratory resources that promote science learning. Research-based experiences are planned collaboratively with graduate students and instructors and are evaluated for application to classroom settings.

A variety of innovative instructional and assessment strategies are used to accomplish the objectives of this course: learning cycle/constructivist approach, active learning, team teaching, cooperative learning, integrated instruction, technology-based investigations, and problem/project-based assignments and assessments.

Student learning focuses on four areas. Students first learn how to solve problems in engineering science. They then use the skills they have been taught to solve problems dealing with materials. Innovative teaching methods are modeled to the students by the faculty team. Finally, the students create lessons based on what they have learned and teach them to others. We have had them teach the lessons to each other, to groups of in-service teachers, and to groups of fourth-grade students at a local elementary school. The last two groups are part of a deliberate outreach program to reach people beyond the boundaries of our university with what we are doing.

The students learn about the atomic structure of metals, ceramics, polymers, and composite materials. They learn how this internal structure affects the physical and chemical properties of the materials. They also learn how this internal structure affects the mechanical properties of the materials. Specific examples that are used include materials-related problems with space transportation systems and with the International Space Station.

Experiential learning is an important part of this course. The need for this is described in the National Science Education Standards: "Conducting scientific inquiry requires that students have easy, equitable, and frequent opportunities to use a wide range of equipment, materials, supplies, and other resources for experimentation and direct investigation of phenomena."[2]

A significant aspect of this course is the extensive involvement of our students with experimental work. Our goal is to introduce pre-service teachers to principles, applications, and technologies that can readily be implemented in their future classrooms. Details of this have previously been reported by the authors[3].

Outreach from Within the Class

Outreach to In-Service Teachers Through a Workshop

One of the goals of this course was to create a workshop for area teachers that would be led by our students. All of our students participated in a half-day in-service training—designed and led by the students. In small groups the students guided teachers through problem solving activities that they in turn could use in their classrooms. Students modeled the same pedagogical techniques (cooperative learning, indirect teaching, constructivism, etc.) that they had experienced in their class. Participating teachers were delighted with the results. Here are a few of the typical comments made on their evaluations of the workshop:

- *This was a wonderful experience! The students have demonstrated their learning in very interesting ways. Many activities will be extremely useful and fun to use in my classroom. I know my students will love each activity. These are very useful both to demonstrate scientific principles and to use as activities when students want to do FUN activities.*

- *The students did a wonderful job, and their lessons were demonstrated in a very professional manner. Each one of these students will be a great teacher. PLEASE have more workshops. I would love more opportunities to explore new ideas and to get motivated to use these activities in my classroom.*

- *This is the best workshop that I have EVER been to. All of the activities allowed us to be hands-on. Everything that was learned today will be transported, proudly, into the classroom. Any age student would benefit greatly from these techniques. Wonderful Workshop!*

- *This was a wonderful opportunity for the Tech students to build their skills. The presentations were well prepared as were the lesson plans. I would love to see all of the presenters again. The material will be easy to use in the classroom. PLEASE do this again.*

! *I thought this was an excellent educational opportunity. The students were well prepared; there were a wide variety of activities presented. It gave the students experience and teachers were exposed to new content and methods.*

Outreach to Elementary Students and Their Teachers

In addition to the experiments performed in our class, our students were required to create a hands-on laboratory teaching lesson that was presented in two different settings. The first one was to a workshop of in-service teachers. The second one was to groups of fourth-grade students at a nearby elementary school. In this setting both the fourth grade students and their teachers got to observe what we were doing.

The students had to create complete lesson plans that could be used to teach this to others. Many of these lessons seemed "easy" to the engineering faculty involved but were not easy for the teachers nor their elementary-age students. It is a challenge to create experiments that demonstrate science and the scientific method to students of elementary age. Many of these concepts were new to our students (education majors, most of them were sophomores).

We wanted to have our students internalize what they have learned. One way to do this is to have them present what they have learned to others. We wanted to communicate to the K-12 students and in-service teachers that science and engineering could be fun. We also wanted to communicate this to our own students. Many of them were very nervous about doing science and engineering things when the class began.

Examples of the Student-created Labs Included:

1. Measured effect of small amounts of caffeine on pulse rate by having students drink different liquids and then measure their pulse. This is shown in Figure 1 below. In this photo students are measuring their pulse after having had a small drink. Some drinks had no caffeine, others had differing amounts of caffeine. The effect of caffeine on increasing pulse rate could be clearly seen.

Figure 1–Caffeine Experiment

2. Qualitative measurement of the density of liquids by examining which ones will support others. Students put liquids of different types in a clear glass cylinder. This is shown in Figure 2 below.

Figure 2–Liquid Density Experiment

3. Illustration of the effect of air pressure by causing a boiled egg to go through an opening in a bottle that is smaller than it is. This is shown in Figure 3 below.

Figure 3–Air Pressure and Egg Experiment

4. Center of gravity experiment. Students examined center of gravity issues related to their own bodies by several different experiments. Two of them are shown below in Figure 4.

Figure 4–Center of Gravity Experiments

Both the students and their teachers enjoyed the presentations. The following teacher comments were typical:

- *Students loved the activities and trying out the experiments.*
- *Presenters were very enthusiastic. Students enjoyed the activities and the lesson.*
- *Great experiment! Very appropriate for this age group.*

Outreach as a Result of the Class

Louisiana Tech has now received a second phase grant from the NOVA project. We have two main goals in this second phase. We will continue to teach our course and make further refinements. The main aspect of this second phase is to disseminate what we have done. We believe that the course we have created and the way we have taught the course can be models for similar efforts in other universities. As such we have had deliberate outreach efforts this past year. Some of them are discussed below. These are in addition to the outreaches described above which were part of the class itself.

Presentations at Science Teacher's Conferences

One of the author's made a presentation at the 2001 Louisiana Science Teachers Associate meeting in December 2001[4]. We shared a couple of our hands on laboratory problems, and demonstrated how they can be used in a middle-school classroom. The presentation was very well received by the teachers who were in the workshop.

Presentations at ASEE Conferences

The authors would like to see more engineering faculty incorporate active learning into their classrooms. We would also like to see more engineering faculty become involved with teacher education and outreach to the K-12 community. As a result of this goal, we have made presentations about the content and teaching methods of this class to the 2000 and 2001 ASEE National Conferences[3,5]. This presentation at the ASEE/GSW Regional conference emphasizes the outreach to the educational community that has occurred as a result of this course (both within the pre-service college teaching area as well as directly with K-12 teachers and students).

Presentations at NOVA Conferences

The NOVA project has regional conferences where math/science/engineering faculty can get together with education faculty to discuss ways to improve K-12 math and science education. At the November 2001 Regional Conference we made a presentation as a successful example program.

We have also made presentations at the national NOVA conferences in 2000[6], 2001[7,8], and 2002[9]. These conferences are different in scope than the regional ones. The regional ones are an outreach to faculty who have not participated in these educational reform activities. The national conference is composed of universities that have been involved in the program. Here we are sharing with each other what we have learned. Since Louisiana Tech University is one of the few universities which has engineering involvement in the NOVA program, we are able to learn about a wide variety of methods and outreach activities that can be done in other science areas.

Louisiana Tech University NOVA Workshop June 2002

We will be having a workshop at Louisiana Tech University in early June 2002. This workshop is aimed at both content (math/science/engineering) as well as education faculty. During this workshop, the attendees will get hands-on experience in ways to teach engineering science to non-engineers. It is hoped that the attendees will go back to their home universities and start similar courses/programs of their own.

Outreach You Can do on Your Campus

There are a variety of approaches you can take to begin an outreach program. One possibility is to follow our example and create a new course. This may be too big a step for some faculty to take all at once. An alternative step would be to incorporate outreach in other classes. For example, in our Mechanical Engineering senior seminar, we have the students prepare and give a technical presentation during the course. Occasionally we have had these senior seminar students make presentations about science related topics in junior high class rooms. This fulfills their class requirement of learning how to make presentations and also exposures junior high students (and their teachers) to the world of engineering.

Similar outreach programs can be developed through your engineering professional societies. This is something that might be supported by your admissions program as part of their outreach activities.

Benefits of these activities to engineering professors

There are four significant benefits to engineering faculty members who become involved in activities such as has described in this paper. First, these sorts of activities will help increase the technological literacy of our society, which will make it easier for engineers to do the things they really want to do. Secondly, exposure of engineering concepts to K-12 students may encourage some of them to pursue engineering when they get to college age. This can only be a benefit to our engineering profession. Some faculty may object to the suggestions in this paper, because they have the attitude that this is not real engineering. We would assert that our class, while not traditional engineering, certainly fits the category of pre-engineering. We are using this class to present engineering in a way that can excite others to join our profession.

A third major, though indirect, benefit to the engineering professor who begins to do the sorts of things we have described in this paper, is in the improvement of her teaching. The authors have been exposed to what are new ways of teaching (at least new to us). The first author has incorporated many of these teaching techniques into several traditional engineering courses such as materials engineering and a combined statics/strength course. Our engineering students are benefitting today from our more creative teaching styles.

A fourth benefit is the personal and professional growth of the engineering faculty member. We have found our involvement in these activities to among the more rewarding and enjoyable things we have done since we became professors. We have seen this benefit in other faculty who have also become more creative in their profession.

Conclusions

We have reported on what we believe are successful outreach efforts, presenting engineering concepts to faculty, college students, in-service teachers, and K-12 students who otherwise would not have learned such concepts. This has been done at relatively low cost. Financial support from project NOVA has been very important in getting this process started. However, many universities could create similar programs without the outside support.

These sorts of activities are new to most engineering faculty members. We encourage other engineering faculty members to think outside the box and become involved in similar activities.

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