Using Laboratories to Teach Engineering Skills to Future Teachers

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Abstract

During the 1999-2000 academic year, the authors created and offered to elementary and middle school pre-service teachers a course on engineering problem solving. This course was designed to build the knowledge base and strengthen the confidence of future teachers when working with science, engineering, and mathematics principles using laboratory-based activities as the foundation for learning.

Using the theme "Our Material World", the authors sought to integrate concepts and principles involving physical, mechanical and chemical behavior of materials as a means to teach engineering problem solving skills. Through the use of frequent laboratory exercises, our goal was to "demystify" for these future teachers some of the fundamental ideas of science and engineering and to heighten their interest and skill level in effectively communicating these ideas to K-12 students.

In the first offering of this course (Spring 2000), we initiated the process of "engineering problem solving" with laboratory-based activities by first forming teams to promote collegiality among the pre-service teachers and to provide a supportive framework for their entrance into potentially unfamiliar territory of problem solving from an engineering standpoint. Team formation was accompanied by a strong commitment to regular "teaming" activities providing ample opportunities for students to literally put their "hands to the task" of experimenting with the new concepts to be learned. Mixed with a lively interaction among the three faculty members (and the students themselves) this quickly broke down many barriers to students' actively and cooperatively learning new concepts.

The course was taught in a cooperative learning environment, integrating numerous hands-on activities with brief lectures coordinated to provide "just-in-time" information for current team activities. By *doing* rather than merely observing, students engaged in "constructivist" instructional techniques.

1. Introduction

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.

In the spirit of NOVA's mission, the authors developed this course with three specific goals in mind:

- To improve the science and engineering problem-solving skills of pre-service teachers
- To model effective teaching methods to the students
- To provide opportunities for the students to create their own problem-solving strategies and modules and practice communicating them to others.

The critical need for reform-minded courses involving faculty, not only from Education but from Science and Engineering as well, is seen in light of a recent initiative begun jointly by the state of Louisiana's Board of Regents and Board of Elementary and Secondary Education. In May 2000, endorsing a report by a Blue Ribbon Commission on Teacher Quality (http://blackboard.lcet.state.la.us/courses/ScienceConsortium/; user name: Blueribbon; password: blueribbon), the two boards instituted new guidelines for teacher preparation. Noting that "teacher preparation is the responsibility of the entire college/university, not just the education program unit, these guidelines shall consider issues which pertain to the college/university at large". As in many states, science and mathematics education have been identified as "critical certification shortage areas". The introduction of our engineering problem-solving course to education majors is therefore quite timely.

2. Course description and conduct

Our 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. During the spring 2000 quarter it was taught in three 2–hour blocks. This allowed us to integrate the labs and lecture into our cooperative learning environment. The purpose of the labs is two–fold; to provide students with hands-on experiences in the behavior of materials, and to model 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 were taught. This course has been developed in an integrative manner, seeking to utilize engineering, all science disciplines, mathematics, and technology for creative problem solving as demonstrated through process skills and product outcomes. Both in the initial course development stage and with subsequent assessment and revisions, close attention is being 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.

During the development of the course considerable care was used in the planning of instruction, use of instructional materials, and evaluation of practices suitable for teaching elementary and secondary school students. Methods for teaching science, mathematics and engineering content to elementary and secondary students were evaluated for appropriateness. Strengths and limitations of a variety of teaching methods were considered. These methods and practices were then modeled and assessed through the conduct of the course in classroom, laboratory, and in-service experiences. Methodologies included lecture, small group activities, whole group activities, individual participation, reflective writing, alternative assessments, cooperative learning, demonstrations, and technology-based assignments.

3. Course Objectives

The objectives of our course included:

- Discussing the importance of teaching problem solving in today’s elementary/secondary schools.
- Enabling our students to display an increased capacity for solving problems related to engineering science.
- Engaging students in their development of a greater understanding of concepts related to engineering and scientific literacy.
- Relating goals and objectives of engineering science to the elementary/secondary school curriculum as well as state and local standards.
- Facilitating the students’ understanding of the unique characteristics and needs to the elementary/secondary level students as they relate to learning.
- Reflecting on the best instructional and assessment strategies for teaching problem solving in engineering in today's elementary/secondary classrooms.
- Enabling our students to recognize the uniqueness of the special learners in a classroom.
- Assisting the students in constructing a complete lesson plan and teaching the engineering lesson to both peers and to area elementary teachers.
- Providing an opportunity for students to evaluate computer software and Internet sites for the instruction of engineering science at the elementary/secondary school level.
- Introduce the use of computer-based laboratory (CBL) technology and other digital data acquisition technology in the elementary/secondary curriculum.
- Encourage students in their efforts to strengthen a positive attitude about integrating problem solving activities related to engineering science into the elementary/secondary curriculum.

4. Course Requirements

The number of student activities in which our pre-service teachers were engaged demonstrate the variety of methodologies centered around our laboratory environment. Building upon the laboratory exercises, students were to conduct the following activities:

- Maintain a current learning log for sponge activities, class notes, and questions/answers.
- Respond to daily journal questions.
- Prepare a lesson plan to be placed in the NASA Resource Center.
- Design and prepare a student-centered classroom lesson plan for an

elementary/secondary classroom, modeled after our laboratory course structure.
- Participate in an in-service workshop for area teachers on a designated Saturday.

5. Laboratory activities

Laboratory experiments composed a major portion of this class. Our goal was to introduce the students to many experiments they could actually do in their own classrooms. Through these experiments, students not only learned or reinforced science, math, and engineering principles; they also practiced skills such as data measurement and analysis, graphing or tabulation, and fundamental statistics.

Some of the laboratory experiences are described below:

- Examine how materials respond to temperature changes by recording the rates at which aluminum, glass, and polymeric soft drink containers cool down when placed in an ice chest.
- Examine crystal structure of metals by making models of unit cells using styrofoam balls and wooden sticks.
- Examine temperature effects on metal behavior by doing Charpy impact tests on aluminum and steel samples at room temperature and the temperature of liquid nitrogen (-320 ºF).
- Examine how metals respond to loads by doing tensile tests on aluminum and steel tensile samples.
- Examine the concept of fatigue by performing fatigue experiments on paper clips.
- Examine viscoelastic behavior of materials by making and observing the behavior of a “silly putty” type material.
- Measured diffusion rates of different dyes onto filter paper
- Learn about rates of change through studying pH, temperature, and humidity in specifically designed experiments.

The details of two of our laboratory exercises serve to further illustrate the experiences developed in the course.

<u>Rates of change</u>

The objective of this exercise was to orient students to the many processes encountered daily involving rate changes. The class opened with a discussion of time dependent processes in everyday living including things such as driving on a trip, dissolving sugar in a cup of coffee, or cooking a meal. We then moved to a series of experiments involving changes in temperature, pH, color chromatography, and humidity of a flowing air stream. As an illustration, the temperature experiment involved measuring the temperature change of a hot plate with a surface thermometer. The thermometer was placed on a cold surface and the hot plate turned to a chosen setting. Temperature data was then collected periodically and plotted on a time graph. The slope of the linear region of temperature increase was highlighted as the rate of temperature increase for this system. This exercise engaged the students in their discovery and development of several new skills and concepts including experiment planning and setup, data measurement and representation through graphical means, and data analysis to understand the rate of change for a process. Similar exercises were developed for the other parameters studied.

Fatigue

Students were introduced to the concept of fatigue, and how repeated loading of a part can cause failure at stresses below the yield strength of the material. This was illustrated by having each student do fatigue experiments on two different sizes of paper clips. This example was chosen since it is something that almost everyone has done at some time in his life—bending a paper clip until it breaks.

This experiment illustrated some of the problems involved in interpreting fatigue data. In particular, the wide range of results was used in two ways. We examined the results and discussed which lifetime should we use: the minimum lifetime or some statistical type of average? This included such issues as whether using the minimum value would require too much material, for it greatly underestimates what the actual lifetime might be. On the other hand, using only a mean value of lifetime means that half of your parts will fail before you would have expected them to. What is the best representation of the fatigue life is not a simple question.

We used this fatigue experiment to introduce the students to several aspects of statistics. They determined the mean, median, mode, and standard deviation of the lifetimes. One of the paper clip types had a smaller standard deviation on its lifetime and this was used to illustrate that its data was more uniform.

Since the first offering of this course (spring 2000), most of the class material has been placed on the web (www.latech.edu/~jordan/NOVA/index.htm). This will enhance student access to ideas and concepts with the next course offering and, with further development, can provide the course to "in-service" teachers at locations remote to the Louisiana Tech campus.

6. Course Assessment

One of our goals for this course was to promote reform-based teaching and assessment strategies among pre-service teachers by immersing them in instructional techniques that modeled a constructivist approach. The focus was on *doing* science rather than merely acquiring isolated facts of content knowledge. Students were asked to construct information in ways that were meaningful to them. The instructors encouraged students to connect new learning to previous experience, to ask questions, to explore a wide range of possible answers to their own questions, and to construct their own conclusions. Incorporated in this context were certain aspects common to other teaching models such as cooperative learning, thinking inductively, nondirective teaching, teaching to multiple intelligences, and efficacy of instruction for all learners.

Publications from NSF[1] , NSTA[2,3], AAAS[4], and NCEE [5], have called for certain curriculum strategies that go right to the heart of the teaching/learning experience. Anderson [6] synthesizes the perspective and recommendations of these publications by national science education organizations as " . . . 1) integrating themes in subject matter, 2) teaching for understanding, 3) making connections between subject matter and its applications, and 4) reaching all students--not just the elite--with rigorous content and attention to critical thinking". Thus it can be seen that the methodologies used in teaching this course had a well researched and broad base of support.

Yager [7] stipulates that most constructivist teachers promote group learning, where students in small groups discuss approaches to a given problem and work together to solve problems. Inquiry lessons should be highly interactive so that teachers and students take on equal roles where ideas are concerned. Students learn best in an environment that combines dialogue with other students, experimentation, and discussion with the teacher.

McIntosh [8] (1995) states that:

We need to give students the opportunity to practice problem solving that is more realistic and requires them do to more of the work. I think this type of activity combined with meaningful post-lab discussion about what happened, what thinking processes were used, and what skills the students need to practice is a good way to give students good problem-solving experience.

In all each of our lessons we used small group problem solving activities which were followed by discussions of not only the results, but the metacognitive implications involved. Most lessons included the five essential elements to a constructivist lesson.

These basics include[9] :
1) activating the prior knowledge of the learner,
2) having the learner acquire knowledge through direct interaction with materials and/or other learners,
3) conceptually developing the acquired knowledge,
4) applying the new knowledge, and
5) reflecting on the new knowledge.

It was our hypothesis that students in this class would make gains in positive attitudes towards doing and teaching problem solving in engineering if we used a curriculum design that capitalized on the students' natural curiosity. Siversten [10] (1993) reports, "Studies have shown that the new curricula [i.e. constructivist oriented] were generally more effective than traditional programs in improving student performance on cognitive measures and raising attitudes about science" (p. 1). We found this to be true in our case.

On a comparison of mean scores from a pre- and post- *Survey of Attitudes About Problem Solving in Engineering for Teachers* students showed a significant positive attitude shift on 17 of the 20 test items dealing with their perceptions of the field of engineering, their ability to do engineering problem solving, and their ability to teach problem solving in the classroom within an engineering context. Our students clearly gained an appreciation for the field of engineering along with a newfound confidence in their ability to solve real life problems having to do with engineering.

Their gains were not only reflected quantitatively on the attitude survey, but also qualitatively in their daily journal writings. Typical entries from the students were these:

The things that I like most about this class were the experiments we did. From the silly putty to the sponge [creative thinking] activities. . . . I also found that I do have a little bit of *science knowledge. From discovering that the scientific name for plastics is polymers to actually going to an engineering lab [I am now] able to relate to conversations that my friends are having. Before that I would just listen. Now I can offer my two cents. After finishing this course I have a new found interest in science related areas.*

I thought it was so much fun learning and doing activities that we can do with our students when we become teachers. I also liked how we learned about chemical engineering and materials engineering and how the understanding of these made the activities not only fun, but also a learning experience!

I enjoy many things in this class. Learning how to incorporate problem-solving techniques into the classroom was especially interesting. I enjoyed learning about cooperative learning. It provided me with valuable insight to how to incorporate cooperative learning and problem solving techniques.

Everything we did was "hands on!" It was great. This is the best fun I've had in any class in my entire 4 1/2 years in college.

[My favorite things about this class were] hands-on activities, interaction among students, interaction with teachers, and the comfort level in the classroom which made it so easy to ask questions. The combination of professors was just cool and greatly added to the learning.

[What I liked about this class was] the cooperative group settings. The "laid back" environment approach in learning some of the different engineering concepts of this course material. I loved the sponge activities in the beginning of the class. They were fun and very relative for future use in our classrooms. Great motivators! I enjoyed the enthusiasm, the down to earth" approach, and the "serious side." All three combined instructors made this course a SUCCESS! It was great, and I recommend this course to all education majors!

Another goal we had for our 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 inservice 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.

I think it was a great opportunity for the students to deal with REAL teachers. The students did a GREAT gob. They were very organized and used super activities. I took more away from this workshop than most others. Way to go, Tech Students! If any of your students would like to do any of these activities in my classroom, they are always welcome!!

7. Conclusions

While we are still relatively early in this process of developing and refining a laboratory-based course for pre-service teachers, the enthusiasm and receptiveness of our participants to date highlights the tremendous potential for impacting the preparation for future teachers entering education at all levels.

Steps to educational reform are often slow and arduous. Yet, the value of time and effort invested by teams of engineering, science, and education faculty in the process of training our future teachers cannot be overstated.

Bibliography

1. National Science Foundation (1993). Science instructional materials: preschool-high school. Washington, DC: Directorate of Education and Human Resources, Division of Elementary, Secondary and Informal Education.
2. National Science Teachers Association (NSTA). (1992). Scope, sequence, and coordination of secondary school science. Vol. 2. Relevant research. Arlington, VA
3. National Science Teachers Association (NSTA). (1993). Scope, sequence, and coordination of secondary school science. Vol 1. The content core: A guide for curriculum designers. (Rev. ed.). Arlington, VA.
4. American Association for the Advancement of Science (AAAS). (1993). Benchmarks for science literacy: Project 2061. New York, NY: Oxford University Press.
5. National Education Goals Report. (1993). Summary guide -- the national education goals report: Building the best. Washington, D. C.
6. Anderson, R. (1995). Curriculum and reform: Dilemmas and promise. Phi Delta Kappan 1, 33-36.

7. Yager, R. (1991). The constructivist learning model -- towards real reform in science education. The Science Teacher, 58 (1), 52-57.
8. McIntosh, T. (1995). Problem-solving practice -- challenging students to design experiments and organize data. The Science Teacher, 62 (1), 48-50.
9. Zahorik, J. (1995). Constructivist teaching. Bloomington, IN: Phi Delta Kappa Educational Foundation.
10. Sivertsen. M. (1993). State of the art: Transforming ideas for teaching and learning science. Washington, D.C.: U. S. Department of Education, OERI Education Information.

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