

Creating a Course in Engineering Problem Solving for Future Teachers

William Jordan, Bill Elmore, Debbie Silver
Louisiana Tech University

Abstract

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 instruction¹. One way to improve K-12 science education is to improve current knowledge and preparation of the future teachers themselves. This project moves toward that end.

Louisiana Tech University's undergraduate engineering program has been significantly modified during the past two 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. To deal with that issue, we 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.

I. Introduction

The health of science and engineering tomorrow depends on improved mathematics and science preparation of our students today. The national interest is now a national imperative. The National Science Foundation (NSF) has stated in regard to declining performance among our nation's K-12 students that the construction of knowledge about teaching and learning is evolving faster than institutions and bureaucracies can respond. NSF recognizes that science teachers exercise key roles in implementing effective reforms. It is, therefore, imperative that institutions of higher learning ensure that science teaching methods for preservice teachers be specifically related to the teaching/learning process as it applies to science. Experiences should be planned collaboratively with professional practitioners in the fields of education, science education, mathematics, engineering, technology and science. Included should be a myriad of problem solving techniques combined with information and technology that have applications

to real world experiences.

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. The topic of properties of matter is explored through a variety of activities, learning opportunities, and alternative assessments.

The tremendous need for well-trained, motivated science, mathematics, and technology teachers is well documented. Louisiana Tech University is helping to bring innovation into undergraduate education by implementing major reform in both content and pedagogy. Methods involving students in direct experience, inquiry, and collaborative learning are becoming staples of many programs—particularly in the Colleges of Engineering & Science and Education. Our course, *Problem Solving in Engineering Science for Teachers*, grew from the investigators' experience with these and other reform efforts.

II. Present course and sequence

In the 1998/99 school year Louisiana Tech was forced to cut hours from all programs in order to meet the state's new mandates to reduce requisite hours. No additional hours can be added to any education curriculums at this time. Our plan allows substitution of this course for pre-existing physical science courses. For secondary science education majors this course is substituted for the third chemistry course that they would otherwise have taken. For elementary education majors, this course replaces a three-hour physical science course that they would otherwise have been required to take.

III. New/modified course description

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

This course has the following catalog description: "An integrative course to enhance engineering, science, mathematics, and technology literacy of preservice 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.

Problem Solving in Engineering Science for Teachers follows the guidelines set forth in the National Science Teachers Association's (NSTA) position statement on Science Teacher Preparation Standards. While focusing on understanding and developing the major concepts and principles of properties of matter, it helps students conceptualize the inter-connectedness of the sciences, mathematics, and technology. Students relate the study of matter and materials to contemporary, historical, technological, and societal issues. Students are able to locate appropriate resources; design and conduct inquiry-based, open-ended investigations in science; interpret findings; communicate results; and make judgements based on evidence.

Problem Solving in Engineering Science for Teachers has ten main course objectives. At the end of the course the student will be able to:

1. Understand a holistic view of science, minimizing rigid boundaries among the disciplines and recognizing the interconnectedness among the subject areas.
2. Demonstrate a comprehension of current science and technology issues and the relationships among ideas, disciplines, and phenomena.
3. Use assessment tools that are aligned with instruction and consistent with contemporary goals of assessment.
4. Relate scientific literacy to their concepts of teaching and learning.
5. Discuss the importance of science in today's schools.
6. Recognize the uniqueness of special learners in the classroom.
7. Apply basic statistical methods and processes of data analysis to problem solutions.
8. Utilize electronic educational technology to solve problems and present findings.
9. Demonstrate proficiency in using the science processes, investigating phenomena, interpreting findings, and communicating results.
10. Develop a systematic approach to problem solving by:
 - Identifying real world problems dealing with materials.
 - Exploring the limitations presented by the problems.
 - Planning active approaches to seeking solutions.
 - Carrying through with viable solutions.
 - Evaluating what has been accomplished.
 - enabling students to break through potential barriers of unfamiliarity and intimidation in using scientific equipment
 - outlining the steps of scientific inquiry through active learning and teamwork
 - building enthusiasm through energetic coaching and mentoring

Student learning focuses on three areas. They first learn how to solve problems in engineering science. They then use the skills they have been taught to solve problems dealing with materials. Finally, innovative teaching methods are modeled to the students by the faculty team.

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.

This is being accomplished, in part, by the use of the Calculator Based Laboratory™ (CBL)—an integrated system of measurement sensors or probes, a data acquisition unit, and a graphing calculator. The system we’ve selected for use are products of Texas Instruments and Vernier Software. The choice for this system was governed by relatively modest cost, a fast “startup” for new users, and wide variety of options for measuring parameters in physical, chemical, and biological processes. Experiments under consideration include parameters such as temperature, pressure, light, voltage, pH, conductivity, and calorimetry.

We will focus on strengthening the links between verbal descriptions, numerical data acquisition, and graphical representation as means of understanding physical phenomena. The identity and application of functional relationships between independent and dependent variables will be address through expression of mathematical models illustrated with experimental activities.

For example, one critical element in scientific inquiry is the fundamental understanding of rates of change in systems. The CBL system provides a clear approach to setting up an experiment for evaluating a process change with time (e.g. pH or temperature), collecting data at a desired frequency and range, and representing the process change graphically. Further processing of data sets, such as statistical analysis, may be accomplished either through use of the graphing calculator or by importing data sets to a computer. Each of these aspects of experimentation and analysis will be presented to the students in a simple, hands-on approach to provide them with training and skills development.

Students work extensively with using and designing lesson plans for Computer Based Laboratories (CBLs) which will include hardware, software, sensors/probes, graphing

calculators, and other CBL curricular materials. This equipment provides the “hands-on” environment for understanding science principles. Experiments provide an opportunity for students to learn about data acquisition and modeling.

Also used are video probes, computers, the Internet (including NASA’s Strategic Enterprises resources), telecommunication technology, and software designed to enhance learning and presentation skills. Eventually it is hoped that the compressed video program that Louisiana Tech already has in place can be used to offer this course and its outreach programs to classroom teachers and university faculties in other geographic locations.

Diversity issues are addressed through the course design. A variety of instructional and assessment strategies are used to accommodate diversity in learning styles and multiple intelligences. Cooperative groups are heterogeneous and are assigned by the instructors who pay close attention to equity among and within the groups as far as gender, ethnicity, socio-economic class, physical handicaps, and learning abilities. Additionally, instructors model and discuss how to address diverse learning populations in the classroom.

Students are given pre- and post- assessments of attitudes towards teaching science, competency in using process skills to solve problems, and basic content knowledge. A portion of the final grade is determined by gains made on the post-assessments of process skills and content knowledge. Other grades are taken from group projects, individual assignments, and classroom participation.

This course was created as part of the *NASA Opportunities for Visionary Academics* program (NOVA). As such, 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. We 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 shuttle. To increase engine efficiency there is a need to create engines that can run at hotter temperatures. This very crucial operating requirement embodies both mechanical and chemical aspects. This is a topic on which one of the investigators (Jordan) has directly worked during the summers of 1997 and 1998 as part of the Summer Faculty Fellowship Program at Marshall Space Flight Center.

Throughout this course we use examples from these two enterprises to illustrate how materials behave. Through this students gain an appreciation for the difficult problems NASA has to solve in order to fulfill its mission.

IV. Collaborative Efforts

This course builds on the strength of ongoing collaborative efforts within the College of

Engineering & Science (COES) and between the COES and the College of Education (COE). In the COES, all engineering programs are completing the third year of an Integrated Freshman and Sophomore engineering course sequence, characterized by a focus on students teams, team teaching, and experiential learning. The two engineering faculty helping to create this course (Elmore and Jordan) have been significantly involved in this process. This effort has been recognized through recent funding of a state equipment grant for an instructional laboratory and a large grant of over \$600,000 from NSF for institutionalizing our reform efforts in the COES.

The education faculty assists the collaboration by combining the strength of their knowledge of the teaching/learning process with the COES's "hands-on" approach to teaching engineering science principles. Our course brings a tremendous opportunity for secondary and elementary education majors to see science "jump from the page" through challenges to their prior conceptions, interactive discovery of new ideas, and a synthesis of a stronger foundation of knowledge.

V. Assessment

One goal in this course is to promote reform-based teaching and assessment strategies among preservice teachers by immersing them in instructional techniques that model desired outcomes. It is our hypothesis that students in this class will make greater gains in attitudes towards teaching science, in competency in using process skills to solve problems, and in acquiring content knowledge than comparable students who go through more traditional courses.

In order to test our hypothesis, we are using a pre- and post- test quasi-experimental control group design. We compare the mean gains of the experimental group on their attitudes towards teaching, their competencies for using process skills in solving problems, and their content knowledge tests with the mean gains of a control group.

Research shows that in general white male students tend to score higher on tests involving engineering, mathematics, technology, and science. It is hypothesized that this course will help to close the gender and ethnicity gaps in that non-Caucasians and females will make gains similar to those of white male students. We are studying the effect of this program on traditionally under represented groups (i.e. female and ethnic minorities). This is being done by performing a 2 x 2 Factorial Design using pre- and post- test scores on the attitude surveys, process skills competency assessments, and the content knowledge tests. Qualitative data are being collected from journals, assignments, and other artifacts to examine any central themes that emerge in regard to this topic of study.

As part of our self-assessment process the graduate student assistants and the three instructors meet on a regular basis to reflect on what is working, what is not working, and areas that can be improved. Data from formal assessments, informal assessments, journals, and progress towards assigned projects is considered as part of the feedback loop for evaluating and modifying the course design and implementation.

VI. Conclusion

In a society dedicated to preparing our nation's children for the future work place, it is essential that scientific rigor and depth of content are stressed in preparation for both teachers and students. Education reform is a long-term proposition, and steps must be taken to ensure that teachers are well-prepared in the subject and who can help renew, expand, and prepare our talent pool for the 21st century. This course is a first step towards achieving that goal.

Bibliography

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Biographical information

WILLIAM JORDAN is an Associate Professor of Mechanical Engineering at Louisiana Tech University. He has B.S. and M.S. degrees in Metallurgical Engineering from the Colorado School of Mines. He has an M.A. degree from Denver Seminary. His Ph.D. was in mechanics and materials from Texas A & M University. He teaches materials oriented courses and his main research area deals with mechanical behavior of composite materials.

BILL ELMORE, Ph. D., P.E., is Associate Professor and Program Chair, Chemical Engineering Program. His teaching areas include the integrated freshman engineering, chemical engineering unit operations, reactor design, and the senior capstone design sequence. Engineering educational reform, enzyme-based catalytic reactions in micro-scale reactor systems, and biochemical engineering are his current research interests.

DEBBIE SILVER is an Assistant Professor of Education at Louisiana Tech University. She is an experienced classroom teacher whose awards include the State Finalist for the Presidential Award for Excellence in Science Teaching, Louisiana State Science Teacher Association's Outstanding Science Teacher Award, and Louisiana State Teacher of the Year. Her teaching areas include science education, curriculum, and instruction.