AC 2012-4249: E 4 E: ENGINEERING FOR EDUCATORS

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Simona D. Dimitriu practiced engineering since 1981 for 20 years and following a graduate degree in education started teaching science since 2007 and math since 2002. She has been involved in numerous initiatives to integrate engineering in science and math education and combine education research with education practice.

Dr. Thomas Gadsden Jr., Our Lady of the Lake University

Thomas Gadsden is a nationally recognized science educator (45 years), and a recipient of 2006 Distinguished Service Award from National Science Teachers Association and awards from the Council of State Science Supervisors and Association of State Supervisors of Mathematics. He has a B.S. in physics and M.Ed. and Ed.D. degrees in science education (1972), University of Florida. He was a research school physics teacher for 17 years, a Associate Professor of education, University of Florida, Director of Science, K-12, Richardson (Texas) ISD, Head of Education, Superconducting Super Collider Laboratory, Associate Director, Eisenhower National Clearinghouse for Math & Science Education, the Ohio State University. and Associate Professor of physics and chemistry, Our Lady of the Lake University, retired.

E 4 E: Engineering for Educators

Abstract

K-12 science and math education is part of the Administration's American Competitiveness Initiative (ACI). As one part of the larger initiative that seeks to encourage research and development, innovation, and global competitiveness, the education arm of the ACI proposes new federal support to improve the quality of math, science, and technological education in K-12 schools.

Recent data confirm that teaching is not an easy profession: A new study from the National Science Teachers Association, for example, shows that for the past 10 years 50% of teachers leave teaching within their first 5 years if trained traditionally and 80% if they obtain no alternative certifications. Often this is due to the frustration new teachers experience when students show little interest in learning and the teacher has little practical experience with the applications of science and mathematics that could help to motivate and even inspire students.

Yet teaching remains a source of fulfillment and intellectual excitement for many thousands of educators, and continues to speak to the interests and ideals of many young people and mid-career professionals.

So, what can be done to help teachers find new ideas that will attract and excite students to learn difficult subjects such as Mathematics and Science?

There is only one answer: By helping teachers become themselves more interested and excited about these subjects! That means exposing teachers to the most exciting and the least understood profession which is engineering! In doing so we bring them examples and real life applications that will help them correlate theory and controlled experimentation with reality.

Thise paper presents a program initiated at "Our Lady of the Lakes University" and incorporated in a Master's Degree in Education. The program targeted primarily high school Physics teachers but the concept can be easily expanded to the entire spectrum of Math and Science education for all K-12 grades.

Science is the art of obtaining knowledge. Engineering is the art of using knowledge to achieve objectives and solve problems. If we put them together in the class room early enough we have better chances to raise more interested and dedicated students.

Introduction

The American Competitiveness Initiative (ACI) [1] is a federal assistance program intended to help America maintain its global competitiveness through targeted investment in research and development (R&D) and education. K-12 science and math education is part of a larger initiative that seeks support to improve the quality of math, science, and technological education in K-12 schools. One of the reasons for all these efforts is the alarming decline in American STEM (science, technology, engineering, and mathematics) education observed for over the last twenty years.

The 2009 report from the Program for International Student Assessment (PISA) [2] on the performance of 15-year-olds in mathematics and science literacy in 65 countries and other education systems found that in comparison with students in all 64 other countries and education systems, students in the United States on average scored lower than students in 23 countries in math and lower than students in 18 countries in science.

At the same time research data confirm that teaching is not an easy profession: A recent study from the National Center for Education Statistics [3], for example, shows that over 8 percent of public school teachers and 16 percent of private school teachers left the teaching profession in 2008–09. Some of the highest percentage of losses, 10 percent from public schools, and 23 percent from private schools, were from the group of teachers with three years experience or less. Yet teaching remains a source of fulfillment and intellectual excitement for many thousands of educators, and continues to speak to the interests and ideals of many young people and often of mid-career professionals as well.

Problem

Texas has the 8th largest economy in the world, an unemployment rate of 4.8%, and four assets that are drawing more manufacturers to the state: low taxes (no state taxes), tort reform, a central NAFTA location, and a growing population. Engineering is one of the four jobs in most demand in Texas. However, in the Thomas B. Fordham Institute's 2005 report on the State of the State Science Standards, Texas was among 16 states to receive an "F" in science instruction. A 2007 report by the Texas Higher Education Coordinating Board (THECB) showed that between 2004-2007 the number of undergraduates at public schools in Texas earning STEM degrees declined from 14,600 to 13,000, despite a “Closing the Gaps” target of 24,000 STEM degrees by 2010 [4].

The problem presented by these new facts is not new but has becoame more pressing with the development of a global economy. So, how do we help the teachers find new ideas and new methods that will attract and excite students to learn difficult subjects such as Math and Science? How do we empower them to take initiative and develop new projects and lesson plans that will help students accept and overcome the modern world’s technical challenges?

In the 1950s, a famous French mathematician, Hadamard [5], found a massive disconnect between how we *teach* math and science and how mathematicians and scientists actually work. He concluded that what the intellectual tools mathematicians and scientistsy used to accomplish their work was more associated with intuition, visualization, using their sensations, problem solving skills and the all encompassing trial and error manipulations. A closer look reveals a lot of similarities with how engineers work. Yet, we often continue to teach math and science as if they were disconnected from the problem solving approaches of engineering.

A Possible Solution

A readily available solution could be to expose the teachers directly to engineering. This could make them more attracted and excited about math and science subjects. Engineering has the ability to build a bridge that connects classroom lessons with real-world applications providing a deeper understanding of the links between theory and practice.

For the last ten years the Center for Science and Mathematics Education at Our Lady of the Lake University (OLLU) in San Antonio, Texas has been actively involved with improving STEM education (Center’s description in Appendix 1). In 2009 OLLU received a Teacher Quality Enhancement Grant (#471 - flow-through money from the U.S. Department of Education’s Math and Science Partnership program) from the Texas Higher Education Coordinating Board to work with high school science teachers in order to increase their content knowledge and pedagogical skills concerning the physics and engineering of energy systems. The proposed title of the grant was Chemistry, Physics, and Engineering of Energy Systems. Because it was not fully funded the title was changed to Teacher Quality Energy Systems. The funding is flow-through money from the U.S. Department of Education’s Math and Science Partnership program.

The OLLU Energy Systems Teacher Quality Project, in a series of articulated courses and professional development experiences, is designed to build solid and advanced understanding as well as practical experiences of the physics, chemistry, and engineering needed to incorporate energy concepts in 6-12 science courses and to establish competence and confidence required for effective teaching in any of these subject areas or in 4th year science courses. Applications of content include intensive field trips, development of skills in use of scientific tools, data collection/analysis, reflective journaling, and analysis of classroom effectiveness. The project is intended for teachers of underserved populations (especially low income Hispanics) who are or could become teaching out-of-field, emergency credentialed, alternatively certified, or in need of expanded certifications.

Since its beginning, the project's success has led to three expansions and upward amendments to its funding. The final project now includes a third year (2009-2012), a total participation of 43 teachers (including middle school and upper elementary science teachers in schools that feed students into the high schools represented by the original group) and a final budget of $440,000. The grant period ends on April 30, 2013 so it is still a work in progress.

In the spring 2010 semester, as part of the grant, one of the courses PHYS 4491 G - Physics of Energy II (Syllabus in Appendix 2) was assigned to be taught by the author (a professional engineer) and redesigned to correlate all the subjects with real life and engineering applications. The course consisted of lectures, research, laboratories, presentations, and a "shoebox" project. The lectures covered various subjects related to energy and their real life applications. The laboratories were all computer simulations intended to help teachers demonstrate the subjects to their classes in absence of adequate equipment. The research was performed be each student on two course related subjects of their choice and presented to class. This assignment was designed to help the teachers become familiar with finding the necessary engineering-related information on a subject. Finally, the shoebox project was a project that asked each of the teachers to select each one a different subject topic related to applications of energy systems and then design and physically built an experiment or a demonstration with everyday, inexpensive (recycled) materials. It was intended to provide every teacher with inexpensive ideas to create and use class materials that in return will inspire creativity in their students (See Appendix 3).

Results

A total of 14 students were enrolled in that course and all were high school physics teachers pursuing a master's degree in education. The final grade distribution was 10 A+, 3 A's, and one B+. In a follow-up survey all of them rated the course very high and declared that they will use in their classes what they have learned right away. All were in agreement that the concept should be continued and developed for all other STEM subjects. Some of the comments are presented in the Appendix 4. Observations of these teachers in their own classrooms confirm the use of the knowledge they have gained with their own students. Since the project is still in progress, final evaluation data is still being collected and will be presented as a final report in July, 2012.

Conclusions

Following such a promising beginning the Center for Science and Mathematics Education at Our Lady of the Lake University intends to expand in the future the course offerings with engineering applications to more STEM courses. The Center plans to follow the faculty going through this program for a period of five years in order to assess the long term effect of the program.

References

1. American Competitiveness Initiative, Domestic Policy Council, Office of Science and Technology Policy, February 2006.
2. Fleischman, H. L., Hopstock, P. J., Pelczar, M. P., and Shelley, B. E. (2010). *Highlights From PISA 2009: Performance of U.S. 15-Year-Old Students in Reading, Mathematics, and Science Literacy in an International Context* (NCES 2011-004), table 8; data from the Organization for Economic Co-operation and Development (OECD), Program for International Student Assessment (PISA), 2009.
3. U.S. Department of Education, National Center for Education Statistics, Teacher Follow-up Survey (TFS), "Current Teacher Data File" and "Former Teacher Data File," 2008–09.
4. Texas Higher Education Coordinating Board, Division of Planning and Accountability, "Closing the Gaps by 2015: 2007 Progress Report", July 2007.
5. Jacques Hadamard, The Psychology of Invention in the Mathematical Field, Dover Publications, 1954.

Appendix 1

Center for Science and Mathematics Education
Our Lady of the Lake University

Mission Statement:

The Center for Science and Mathematics Education's mission is to revitalize science and mathematics learning, Pre-Kindergarten through College, by inspiring and supporting teachers while reshaping teaching.

Goals:

(1) To provide a graduate program for K-8 teachers, focusing on the state and national standards for Life Science, Earth Science, Physical Science and Mathematics. (2) To provide science and mathematics coursework for teachers teaching in grades 6-12, preparing them to be highly qualified in their field and assist them in preparing their students to be college ready.

Description:

The Center for Science and Mathematics (CSME) will ensure quality science and math instruction by providing teachers graduate courses to enhance their content knowledge and instructional skills, using local, state and national research-based curriculum and instruction. The graduate coursework is designed for fulltime classroom teachers that will attend OLLU part time to enhance their content knowledge and instruction and, ultimately, improve student achievement. The teachers will become campus, district and area science and mathematics leaders by sharing what they have learned at workshops and conferences they have attended and through required individual research. The graduate programs will include a combination of lectures, laboratory experiences, speakers, and field trips. OLLU will continue to provide the following graduate programs for classroom teachers that are still active in the following programs:

- Curriculum and Instruction for Integrated Science for PK-8 grades teachers
- Curriculum and Instruction for Integrated Mathematics for PK-8 grades teachers
- Curriculum and Instruction for Chemistry, Geology, Physics, Biology or Pre-Engineering secondary teachers (can teach dual credit)
- Curriculum and Instruction for Secondary Mathematics for teachers

Appendix 2

OUR I.ADY OF THE LAKE UNIVERSITY

COLLEGE OF ARTS AND SCIENCES

COURSE SYLLABUS

PHYS 4491 G Section 01

Physics of Energy II

Spring 2010

Professor: Dan G. Dimitriu, Ph.D., P.E.

Office Hours: W 8:00 PM, Saturdays after labs, or by appointment

Telephone: (210) 696 4357; **Email:** dgdimitriu@ollusa.edu ; or ddimitriu@alamo.edu

Class Time: W 5:00 PM - 8:00 PM plus six labs on six Saturday mornings from 8:00 AM to Noon

Classroom: Metz 204; **Laboratory:** Metz 201

COURSE DESCRIPTION:

The course will continue in depth study of the fundamental physical principles underlying energy processes and the application of these principles to energy systems in a quantitative, calculus-based environment. The subject topics will be divided into three parts, radiant energy, magnetic and electrical energy, and nuclear energy. Each subject will be connected to real life engineering applications. This is not a survey course.

INSTRUCTIONAL MATERIALS:

Hewitt, P. G., *Conceptual Physics*, Tenth Edition, Pearson Addison Wesley, 2005;

Knight, R. D., *Physics for Scientists and Engineers*, Second Edition, Pearson Addison Wesley, 2008;

Bloomfield, L. A., *How Things Work – The Physics of Everyday Life*, Fourth Edition, J. Wiley, 2010;

Each student will need a scientific calculator.

STUDENT ACADEMIC OUTCOMES:

1. An understanding of the basic physical principles of radiant energy and waves as applied to sound, light, and magnetism.
2. An increased understanding of the basic physical principles of magnetic and electrical energy with applications in power generation and distribution.
3. An increased understanding of the basic physical principles of nuclear energy and its applications in various industries.
4. The ability to independently conduct, understand and draw conclusions from a variety of physics experiments related to acoustics, light, electromagnetism, and atomic structures.
5. The ability to apply critical thinking and scientific reasoning, along with mathematical tools in solving problems related to various energy systems.
6. Exhibit an understanding of physical concepts by performing and discussing physics demonstrations and real life applications related to various forms of energy.
7. An increased understanding of the correlation between TEKS requirements and Physics of Energy everyday applications.

WEIGHT	MEANS OF ASSESSMENT	(OUTCOMES)
20%	Three Section Exams	(1,2,3)
25%	Laboratory Experiments & Reports	(1,2,3,4,5)
25%	Student presentations, homework, quizzes, and attendance	(1,2,3,4,5,6)
30%	Individual Student Portfolio which will include:	(1,2,3,4,5,6,7)

a) (10%) - Weekly executive summary of key points with relation to the TEKS for student's grade level; Typed and submitted at the beginning of following week's class together with the assigned homework.
b) (10%) - Reviews of two electronic instructional technology resources that will enhance students' content understanding for each chapter covered. Typed and submitted weekly.
c) (10%) - One Shoebox Science Project to be presented at the end of semester

Grades will not be issued until each Portfolio item has been completed!

COURSE STRUCTURE

Weekly classes with two hour lecture and one hour student presentations will be held on Wednesdays between 5:00 PM and 8:00 PM. There are six labs scheduled on Saturdays throughout the semester from 9:00 AM to Noon. (See Course Outline)

STUDENT PRESENTATIONS

Each student must choose two subjects from different chapters from the book "How Things Work" and present them in a PowerPoint format to the class at the appropriate time. The presentations will be graded for content and style by the professor and peers on anonymous ballots. The eligible subjects must be selected from the following chapters: 7, 9, 10, 11, 12, 13, 14, 15, and 16. In case there are not enough subjects, the second presentation may be presented by teams of two students.

SHOEBOX SCIENCE PROJECTS

Each student is required to develop one shoebox science project based on a specific TEK Physics problem from their particular grade level. The shoebox projects will be presented at the end of semester instead of a final exam. (See Course Outline) **Please note: Lack of completion of this assignment will result in loss of one letter grade!**

GRADING SCALE:

A (100 - 90), **B** (89.9 - 80), **C** (79.9 - 70), **D** (69,9 - 65), **F** (< 65); **P/F** (70 and above)

ATTENDANCE POLICY:

Students are expected to attend all classes and laboratory sessions. Excused absences must be cleared with the professor. Any student missing three (3) or more classes will be dropped from the class.

STATEMENT ON STUDENTS WITH DISABILITIES:

Any student with a documented disability is entitled to reasonable assistance and resources to enable them to function in a capacity to meet the course requirements.

Appendix 3

Creative Shoebox Experiment Ideas for School Projects

Shoebox Projects should be a part of every school year's activities and in just about every grade they should serve as wonderful learning tools. They can be used to learn the arts and crafts of making things and at the same time they should be used to teach and learn about specific subjects such as laws and applications of Physics, Chemistry, etc…. This specification will provide some guidelines on how to make a successful shoebox project and write the instructions on how to build it and how to use it in class to teach a subject from Physics topics.

Specification

Start by selecting an appropriate topic for your project. It should be a law of Physics or a physical phenomenon related to Energy that would help students understand it better through an experiment or demonstration. Describe which class activities will be included in it and how will they will help you teach that subject. Indicate the appropriate TEKS references. You may even decide to make this shoe box project as a half science project building and half for testing it in a competition between teams -w. Whatever it takes to keep students interested and helps them learn the subject. Define the necessary steps to guide the students throughout the experiment and select the needed data and the number of readings or repetitions required to complete the experiment/demo. Make sure that the duration of the entire activity, from set-up to conclusions, does not exceed 30 minutes.

Write a detailed description of the project that should include:

- Presentation of the physical law/phenomenon;
- Indicate if the project is an experiment or a demonstration and if it is to be done in class by the students or prepared by the teacher in advance;
- List the steps needed in successive order and the expected times to perform them;
- If needed, provide a list of expected results and values for guidance;
- Provide a list of materials indicating their source and estimated costs;
- Indicate if there are any preparatory operations (bending, folding, cutting, etc…);
- Describe in detail how to make it, how to put it together, and how to operate it. Provide up to five descriptive pictures of the project. (Remember, everybody will receive only the written part so, they have to be able to reproduce the project on their own following just your instructions! Now that's Engineering!);
- Conclude with a list of expected outcomes and follow-up discussions;
- Put the printed instructions and parts list together with all the parts in a shoebox (container) and present the project to the class when indicated.

Materials

Think outside the shoebox! There is no need to run out and buy a new pair of shoes if you don't have a shoebox. A more than adequate box can be made from scraps of cardboard or even a few cereal boxes cut and taped together. You may use the box as support or as part of your experiment/demo. And there is no need even to make a typical shoebox shape. It can be an envelope, a bag, a jar, a coffin, or anything that can hold your contraption. Be creative in the shape you make. It adds a dimension of interest to the project.

Please keep the cost of materials to an absolute low, since the recovery funds do not trickle down to our levels. Use as many recycled materials as possible so you might use them also as an example of a greener economy!

Add a Fact Sheet – This is a great tool that should be added to every experiment/demo describing where in real life the respective law/phenomenon is applied.

Whatever project you choose to make you should take a little time to make it different and unique and there are lots of creative ways to do that. **Have fun with your project!**

Appendix 4

On a questionnaire given to the participants, every one reported increased knowledge and a positive impact on themselves and their teaching. Every participant indicated he or she was using the content and teaching strategies learned in the project. Here are examples of statements made on the questionnaire:

"The class and program has had a great impact on my teaching …"

"I view teaching physics through a new lens … I now use applications of physics to drive learning in my class."

"For the first time I am not just using labs developed by others. I now am at a level where I have started to develop my own labs."

"I have been able to interject the use of technology in my classes…"

"Now I am able to draw conclusions from unexpected results…"

"The use of multiple texts and the exposure to different teaching strategies was very helpful…"

"I have been able to tie real world applications to physics concepts."

"I will be rewriting some of my labs and PowerPoints…"

"I have started pushing energy more in my class."

"I love the idea of introducing students to the practical applications of what they learn."