Adding E into STEM to Teach & Inspire Future Engineers

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ABSTRACT

The 21st century's dramatic technological revolution requires graduating more engineers to cope with new global exigencies and to develop new manufacturing processes and products, as well as manage energy, transportation and communications systems to prevent new and redress old environmental problems, create pioneering health care devices, and, in general, make technology respond to ever increasing demands (Flexner Report, 2007, Arnett and Van Horn, 2009). Despite this increased need for engineering professionals, the numbers of students studying engineering have declined in recent years, both in the United States and globally (Johnson and Russell, 2006). Many factors have contributed to this decline – including the difficulty of the curriculum, lack of well-prepared K-12 Sience , Technology , Engineering and Math(STEM) teachers, and the attractiveness of alternate paths to good technical jobs and uncertain employment paths for engineering graduates (Besterfield-Sacre Atman, & Schulman, 1997). Building student passion for engineering and science from an early age is one of the most important factors to prepare younger generations to become future engineers. Students need knowledge and inspiration in K-12 math and science classrooms, particularly in K-12 schools. Teachers can integrate their math and science knowledge into engineering principles in ways that engage learners in the world of the engineer. This paper will discuss the curricular innovations developed by Dr. Darwish to respond to the needs of in-service middle school teachers (master's students) who are integrating engineering principles into their curricula.

Key words: STEM education, STEM knowledge, Engineering, K-12 teachers education, Pedagogical strategies

Introduction

Former U.S. Secretary of Education William Bennett blamed the US education system, stating "America's K-12 and post-secondary education systems are failing in their mission to prepare our nation's children and young adults in science, technology, engineering and math -- the STEM fields. And it is a national disaster in the making". To meet the needs for a STEM capable citizenry, a workforce to fulfill the needs for new technological revolutionized world and prepare STEM experts, we must focus on three goals. We must provide all students, including girls and minorities who are underrepresented in these fields, to be proficient in STEM subjects with an education that includes a solid foundation in science, technology, engineering, and mathematics (STEM) (NSF, 2011; PCAST,

2012). We also need to encourage the students of today to pursue careers in STEM-related fields. We must prepare STEM teachers to think like scientists, mathematicians, and engineers and provide understanding for the process of scientific and mathematical thinking. Lastly, we must train them on how to conduct hands-on experiences in collecting data through systematic investigations, analyzing/interpreting data, and forming hypotheses with the focus on math/science content integration in engineering concepts (Felder and Brent, 2004).

In order to improve STEM education, we must focus on both preparation and inspiration. Teachers can inspire future engineers with two attributes they possess, their deep STEM content knowledge and their pedagogical skills. These teachers can model the ways in which math and science concepts are applied in the engineering world.

TTU- Middle School Math and Science $(MS)^2$ Teachers

In order to prepare great STEM teachers with the collaboration of College of Education and College of Art and Sciences and College of Engineering TTU- a Middle school Math and Science $(MS)^2$ In service teachers graduate degree program was established. This project was funded by The Greater Texas Foundation and the goal of the (MS)2 Understanding by Design program is to prepare qualified in-service middle school mathematics and science teachers to increase their content expertise as well as effective instructional practice. As per the grant description, *through participation in this Master's degree program, teachers will thrive in an interdisciplinary environment through their experiences in learning communities comprised of a team of mathematics and science teachers as well as university STEM (science, technology, engineering, and mathematics) and education faculty. (MS)2 participants have been engaged in math and science learning for the duration of the project*. Specific goals of the program include:

1. Mathematics and science coursework and education pedagogical courses tailored for middle school teachers.
2. Community building between Texas Tech University faculty and in-service teachers.
3. Collaborative design and implementation of integrated STEM instructional units.
4. Grant proposal writing to solicit funding for instructional materials including lab kits and manipulatives.
5. Development of a cyber-enabled support network and dissemination platform for statewideoutreach.(http://ttumssquare.org/index.php?option=com_content&view=article&id=19&Itemid=27).

A Course: Integrating Math, Science and Engineering

In the summer of 2012, a class was created by Dr. Darwish to train middle school in-service teachers to think like scientists, mathematicians and engineers, with the explicit objective of providing understanding of the processes of scientific and mathematical thinking. Informed by the course catalog, the course provided hands-on experiences for the in-service teachers to develop expertise in collecting data through systematic investigations, analyzing, and interpreting data to form hypotheses with the focus on math/science content integration in engineering concepts. Student learning outcomes of the course is given in table 1.

Table1: **Common Student Learning outcomes: Upon completion of this course**

Learn	*actively and independently acquire, apply and adapt skills and knowledge to develop expertise and a broader understanding of the world as lifelong learners.*
Think	*analytically and creatively to explore ideas, make connections, draw conclusions, and solve problems.*
Communicate	*exchange ideas and information with clarity and originality in multiple contexts.*
Integrate	*demonstrate proficiency in the use of technologies and online resources.*
Appreciate	*diversity and complex environments*

Specific Student Learning Outcomes:

An important goal of this course was to enhance students understanding of mathematical and scientific thinking so they can integrate science, math, technology and engineering into a new trans-disciplinary subject. The course provided a chance for students to make sense of the world rather than learn isolated bits and pieces of phenomena. Through participation in the learning and observing, the modeling provided by the professor, the middle school teachers will be able carry such instruction into their classrooms.

Discrete Skills the Students Learned:

- Understand learning and teaching styles and demonstrate an ability to use a variety of pedagogical strategies to enhance mathematical and scientific thinking in secondary students;
- Demonstrate an ability to use Internet-based tools including that are applicable for secondary classrooms;
- Formulate, articulate, and solve problems;
- Work on a team to design things, and how to present the results of engineering work in oral and written form;
- Demonstrate good technical communications skills;
- Apply content knowledge in science, technology, and math and engineering to solve design-based project challenges;
- Analyze and present electronic data using spreadsheet and word processing software;
- Articulate engineering concepts;
- Design engineering solutions to problems;
- Identify the differences between the various fields of engineering specialization.
- Discuss some basic fundamental engineering concepts and topics;
- Define and describe examples of sustainable energy and development techniques.
- Examples of the use of technology in course delivery & communications;
- Introductory principles of sustainable development and GREEN construction;
- Participate in discussions of engineering ethics;

- Demonstrate improved efficacy of teaching mathematics, science and engineering in secondary education.

Methods of Instruction:

- Topics were introduced through faculty and visiting lecturers, discussions, power point presentations, readings and field trips with heavy emphasis on class discussion and participation. Lesson presentations relied on these instructional strategies:
- Discussion/Questioning
- Problem Finding/Solving
- Independent Learning Discovery
- Peer Critiques
- Collaborative Learning Groups
- Guest lectures, Viewing, Listening, and Discussion
- Online Project Description Postings
- Reflective Response
- Group Brainstorming
- Hands-on Experiences in Simulations
- Projects and Student Presentations.

Simulations-- Basic science math principles and introduction to engineering

In the following categories, students worked with the professor during class time:

- **Engineering Design:**
  Project 1) Design the Best Organizer in the World: introduces students to the field of engineering, the engineering design process, and careers in engineering and technology.

- **Problem Solving and Decision Making :**
  Project 2) Design a Building of the Future: Introduces students to the problems of urban sprawl, estimating area and scale, simple calculations of loads experienced by structures, testing and choosing appropriate materials for construction, structural failure analysis,
  and thermal energy transfer. In the culminating activity students present a scale-model and their plan for an energy efficient multi-use building (Darwish and Agnello, 2010).

- **Introduction about Fluid Mechanics:**
  Project 3) Energy in Fluid Systems: Improve a patented boat design: Introduces students to fundamental concepts of fluid and thermal power and challenges them to apply this concepts to improve an already designed boat discover how it operates, gain insights for design improvements.

- **Introduction to Electricity and Communications:**
  Project 4) Electricity and Communications: Introduces students to qualitative understanding of circuits, Ohms law, and they learn about the function of solar cells, other power generators, and combining circuits into communication systems, consumer electronics, power generation, and alternative energy and environmental issues.

- **Introduction to Viscosity and Polymers:**
  Project 5): Polymer Experiment: Implements students' pursuit of the scientific method, and experiment data collection and analyzing.

Implementation:

The student-centered class was taught through cooperative learning and teaching. Students were expected to take responsibility for their own learning. Focusing on what students would be able to do with their students when they were done with the class, the professor used a variety of instructional methods, techniques and tools (e.g., group learning, individual student research, independent study, joint faculty-student research, active problem based learning, in-class assessment techniques, lecture and discussion).

Science, technology, engineering, and mathematics (STEM) education were used to identify individual subjects but in this course, the concepts were integrated into engineering. Students were exposed to engineering applications of the concepts and built simple machines and other simple engineering tools — activities that could be replicated in their own classrooms. Emphases were placed on a balance between theoretical concepts and practical applications, and also students' use of technology to interface and exchange data among themselves.

Felder and Brent (2004) found students more likely to learn, be more confident, and make more valuable contributions when they felt accepted. The professor acknowledged and affirmed the teachers' content knowledge expertise, as well as their deep knowledge of their students. As a result, the student evaluations were positive as indicated in these statements by the students:

> First day I thought this class was going to be overwhelming but once things picked up, I decided it was going to be an interesting class. I enjoy the idea of human machine team building exercise and the idea of having team leaders; adds a practical aspect-one that can be applied to the real world.
>
> I have really enjoyed the activities I feel that these are good because they are very effective learn the theory and put into practice. It makes me feel good that I can use the ideas to show the how math and science are used to design stuff.
>
> Hands-on, project-based math and science integration in this class showed me how to develop reasoning and understanding.
>
> Engineering design projects were great and based on realistic constraints that professionals in the field may face, such as a change in safety requirements. We thought critically about how to revise our design prototype to satisfy its design goals and meet its scientific requirements.
>
> We learned real engineering design processes. I am more confident now than before to teach these subjects.

It was a great class. I enjoyed it, and I now have a better understanding of science content and how to integrate these concepts into my teaching.

Conclusions

The technological revolution of the 21st century has created a need for more engineering professionals, yet interest in engineering is declining. In order to close this gap in the education system, the academy and the K-12 schools must re-envision STEM subjects in a way that STEM teachers can be equipped to respond to their students' inquisitiveness and expression as advocated by John Dewey (1929). In classrooms where students see the relevance of what they are learning, they can imagine the many possibilities of applying their knowledge. They believe in themselves as able to use science and math to engage in problem solving. They explore the world of engineering where math and science are the means to an end, rather than ends in themselves. Students learn math and science principles and become inspired to be future engineers (Green Report). This year, the course will be offered for a second time, improving upon the initial instructional strategies, refining the implementation of the integrated science and math instruction, and responding to the needs of teachers. Teacher feedback and my own reflection on my teaching practice have been the inspiration of my plans for even better STEM preparation for in-service teachers.

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