An Integrated Interdisciplinary Approach to Engineering Education

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Abstract

This paper presents of a new Master of Science in Teaching curriculum in Engineering Education. Drawing on a multidisciplinary team of faculty members from colleges of Engineering, Education, and Liberal Arts and Sciences, the underlying motive of the proposed curriculum is to strengthen quality of math and science for high school and middle school teacher in mathematics, science, and career technology areas. Emerging technologies, such as nano-technology, energy engineering, homeland security, and modern manufacturing engineering are among the salient content components of the proposed graduate program. Team-based project based learning models concomitant with effective pedagogical practices are utilized to increase accessibility of engineering content material for teachers with non-engineering background.

Introduction

Integration of engineering curriculum to high schools and middle school math and science curriculum is critical in advancing application based learning to positively impact adolescent identify formation towards STEM (Science, Technology, Engineering, Mathematic) fields. In light of the interdisciplinary nature of engineering in terms of its mathematics and science rich content, this curricular integration should enable math, science, and career education teachers to effectively engage their students in engineering-based problem learning. This integration is tackled in three fronts: (1) Pedagogy; (2) Alignment with math and science standards; and (3) Engineering based applications. As such, it is imperative to draw on an interdisciplinary team of university faculty members from Colleges of Engineering and Engineering Technology (CEET), College of Liberal Arts and Sciences (CLAS), and College of Education (CEd), to advance partnerships with school districts in order to strengthen the quality of mathematics and science instructions via engineering based content. It is envisioned that such a partnership between the university and school districts would result in: (1) Producing cluster of teacher leaders in pedagogical content knowledge in engineering and technology; (2) Teacher leaders in collaboration with interdisciplinary team of faculty mentors will develop their own research projects; and (3) Engaging school teachers in research dealing with emerging technologies.

As a result of this MSP partnership, the participating faculty will assume an active strategic role in contributing to the generation of highly qualified and highly effective teachers . Furthermore, such partnerships enable transfer of knowledge flow in engineering and technology from university faculty to middle and high school teachers in order to raise awareness in engineering and technology among their students. This awareness is highly needed in light of the fact that in recent years we have observed a sharp decline in the number of high schools graduates going to engineering.

This paper advances the creation of a new master's degree for high school and middle school teachers in engineering education. Through a collaborative network of STEM faculty members, this master's degree advances a content rich engineering curriculum with special emphasis on emerging technologies such as nanotechnology, homeland security, energy engineering, and modern manufacturing. Integrated to the content is the imbedded coverage on the following important strands: (1) pedagogical content knowledge; (2) adolescent identity formation; (3) Career Awareness; and (4) STEM Literacy.

Master of Science in Teaching in Engineering Education (MST-EE)

The Master of Science in Teaching (M.S.T.) with specialization in Engineering Education prepares teachers with mathematics or science certification to infuse traditional content with the 21st century knowledge and skills associated with emerging critical technologies such as nanotechnology, fuel cells, and modern manufacturing technology. The program integrates mathematics and science standards for teaching and learning into the middle school and high school industrial technology endorsements. The central goal of the program is to empower teachers to implement generative and transformative pedagogy by using research-based instructional practices and emerging engineering content. Four strands permeate the program: (1) active learning through such approaches as project-based learning and guided inquiry, (2) adolescent identity development, (3) action research, and (4) teacher leadership.

Mission: The Master of Science in Teaching (M.S.T.) with specialization in Engineering Education prepares certified middle and high school teachers of mathematics and the sciences to engage their students in authentic engineering content and processes. Such engagement will stimulate interest in mathematics, the sciences, and engineering among adolescent students at a formative time in their academic development.

Educational Objectives: The program leading to the Master of Science in Teaching (M.S.T.) with specialization in Engineering Education is designed to: (1) improve teaching and learning of mathematics, the sciences, and engineering by increasing the knowledge and skills of teachers; (2) implement quality action research, focusing on inquiry and problem-solving skills; and (3) integrate research-based pedagogical practices and content.

Program Requirements

Students must complete at least 33 semester hours of graduate work consisting of the following courses:

IEET 590 - Topics in Engineering and Engineering Technology Credits: 1-3
Selected interdisciplinary topics from various engineering or engineering technology disciplines not offered in regular departmental courses.

TECH 532 - Disaster Preparedness Credits: 3
Organization for survival from natural and human-made disasters. Warning and communication systems, radiological monitoring, shelter management. Fallout shelter experience included.

TLCI 537 - Improvement of Instruction Credits: 3
Investigation and analysis of common problems in teaching. The principles which apply at all levels of instruction.

UEET 601 - Introduction to Emerging Technologies Credits: 3
An overview of emerging technologies for teachers. Introduction to basic concepts of nanotechnology, energy use, fossil fuel resources and energy conversion, fuel cells and their power generation, electronics, applied engineering probability and statistics, applied modern manufacturing and quality control, and the basics of homeland security.
UEET 602 - Nanotechnology and Applications Credits: 3

Introduction to the basic concepts of nanotechnology for educators with a focus on theory of nanotechnology, history of nanotechnology, microelectronics and MEMS, and simple experiments to demonstrate the principles of nanotech. Special emphasis is placed on modeling and use of instructional methods and best practices appropriate for delivery of pedagogical content.

UEET 603 - Introduction to Energy Engineering Credits: 3
Overview of energy use, fossil fuel resources and energy conversion for teachers. Topics include solar energy principles, solar collector, photovoltaic cells and applications; wind energy and wind turbines; nuclear energy principles, nuclear reactors, and power generation; bio-mass and energy conversion; and hydrogen energy, storage, and trans-

portation. Overview of fuel cell, fuel cell types, and applications. Special emphasis on modeling and use of instructional methods and best practices appropriate for delivery of pedagogical content.

UEET 604 - Introduction to Fuel Cell and Fuel Cell Power Generation Credits: 3
Introduction of the basics of fuel cell power generation for teachers. Topics include: introduction to fuel cell; classification, types, and operations of fuel cell; energy conversion process in fuel cell; fuel cell characterization; thermodynamics of electrochemical fuel cell, major components, and operation; irreversibilities, voltage losses, and performance characteristics; fuel cell analysis and design; fuels and fuel processing; thermal and water management; and fuel cell power electronics and power conditioning. Special emphasis on modeling and use of instructional methods and best practices appropriate for delivery of pedagogical content.

UEET 605 - Nanoelectronics and Applications Credits: 3
Introduction to the basic concepts of nanoelectronics for teachers. Use of theory and experiments to demonstrate the principles of nanoelectronics and nanodevices

UEET 606 - Applied Modern Manufacturing and Quality Control Credits: 3
Study of the elements of the entire manufacturing process, including the cost, productivity (throughput), and quality control arenas. Exploration of the relationship between cost, throughput, and quality. Study of optimization principles and the application to manufacturing. The content as well as the pedagogy will be addressed.

UEET 607 - Internship Credits: 3
Provides experiences at industrial sites or research laboratories in emerging technologies such as nanotechnology, fuel cell research, modern manufacturing and quality control, and homeland security. Students are required to spend 20-40 hours per week at practice sites.

UEET 608 - Master's Project Credits: 3
Focuses on a relevant subject area of particular interest to the student in the areas of emerging technologies such as nanotechnology, fuel cell research, modern manufacturing and quality control, and homeland security.

Problem Based Learning

The MST-EE program includes engineering and technology faculty members with content expertise in nanotechnology, energy engineering, modern manufacturing, and homeland security. These fields were selected because each one has an interdisciplinary foundation. For example, understanding nanotechnology involves chemistry, biology, physics, etc. Because the content is with the emerging sciences, participating teachers will be introduced to some of the most advanced and latest technologies. The MST-EE engages the participant teachers in Problem-Based Learning (PBL) centering around problems that are complex, ill-structured, and "messy" – like problems in the real world [2]. These problems must be relevant to learners, so that learners are motivated to solve them. Learners must have some background knowledge, although their knowledge is likely to be incomplete. But, what learners do not know already, they will learn on an "as-needed" basis with support from their teachers. Duch, Groh, and Allen reviewed the research on the effectiveness of PBL, finding that learners develop the "ability to identify information for a particular application" [2, p. 7], and they improve research capabilities. By learning material in the context in which it will be used, both the retention of material and transfer of learning to new situations are enhanced. Learners also learn to work collaboratively and to communicate clearly via PBL [2].

Learners engaged in PBL follow a flexible, recursive process, as outlined by Boud and Feletti [3]. First, learners are presented with a problem. Working in cooperative groups, learners identify existing knowledge and organize their ideas. Learners attempt to define the problem more precisely. As they research aspects of the problem, learners acquire new information, and working together, synthesize solutions. As Duch, Groh, and Allen, put it, "they explore the previous learning issues, integrating their new knowledge into the context of the problem" [2, p. 7]. Complexity increases and new questions arise.

This iterative process can provide the organizational framework for a single class session if research resources are readily available, a series of sessions, or an entire course. As learners progress through a program of study, insights from previous PBL experiences accumulate and are progressively synthesized. Ideally, the whole curriculum becomes a large-scale, in-depth PBL experience [4]. Thus, by engaging in PBL as learners in MST-EE, K-12 teachers are more likely to feel confident and comfortable with the complexity and no-easy-answers climate of PBL and therefore implement it in their own classrooms.

Alignment to National, State, and Endorsement Standards

A major identified need is to align the program to local and state standards for public school students with the state endorsement standards for the secondary Technology endorsement and the middle school Industrial Technology endorsement, national professional societies' educational standards, and with the professional engineering accreditation standards. We needed to align the expectations of the public school student (e.g., Illinois Learning Standards for public school students in mathematics and science) with the expectations of teachers (e.g., National Science Teachers Association, National Council of Teachers of Mathematics, and the International Society for Technology in Education); and with the expectations of the university (e.g., Accreditation Board for Engineering and Technology, ABET).

To develop an overarching framework, team members engaged in a process that was guided by Understanding by Design (UBD) [1], which is similar to a "reverse engineering" procedure. In frequent use by public schools, UBD recommends that curriculum developers engage in "backward design." That is, during Stage 1, curriculum developers first determine desired learning outcomes. During Stage 2, they identify acceptable evidence that learners have achieved these outcomes and which assessments will elicit this evidence. Finally, in Stage 3, curriculum developers plan learning experiences. When this sequence is followed, learning destinations guide the curriculum's route, and all parts of the curriculum are connected in a cohesive manner.

Conclusions

This paper presented the development of a new master of science teaching inn engineering education (MST-EE) to strengthen quality of math and science for high school and middle school teachers. Using a problem based learning approach, the proposed MST-EE program featured special coverage on emerging technologies such as nanotechnology, energy engineering, homeland security and modern manufacturing. In addition, internship programs through industry, national labs, and research mentorship with engineering and science faculty members as an integral part of the program is proposed to better enable teachers in delivering a curriculum through problem-based learning with engineering applications.

References

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