Engineering Implementation in Grades 6-12: Evaluation of the Effectiveness of a Workshop Model

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Abstract

In order to assist math, science, and technology education teachers learn engineering design based content they can use in their classrooms, the Pre-College Engineering for Teachers (PCET) program [1] was developed to provide teachers with professional development training. Through this program, teachers can participate as Mentor teachers who attend a two week workshop called Tufts Engineering Mentor Institute (TEMI), or they can participate in the Satellite programs developed and run by the Mentor teachers the following year. After the introductory workshops, these cohorts of teachers return to their classrooms and implement engineering design projects with their students. One of four participating universities provides faculty and graduate student support to the Mentor teachers throughout the school year. These teachers then provide similar assistance to the participants of the satellite workshop. Thus far, the program has been completed at the high school level, and is in progress at the middle school level. This paper provides a review of the effectiveness of this workshop model at these first two levels.

Introduction

In Massachusetts, many middle school and high school educators need to increase their technical background in engineering and ability to integrate the engineering design process into their classrooms. This need is driven by the statewide curricula [2] and a high stakes testing system implemented throughout the Massachusetts public pre-college educational system [3]. The testing system assesses student knowledge in various areas of the state based curriculum frameworks and is known as the Massachusetts Comprehensive Assessment System (MCAS). The MCAS tests include a technology/engineering section that is presently assessed for students in grades 5, 8 and 10.

In an effort to support this need, a program entitled Pre-college Engineering for Teachers was started in 2002 by Tufts University with a grant from the National Science Foundation. The program will be completed in the summer of 2007, and its goal is to educate K-12 teachers about the engineering design process and to support them during the implementation of this content in their classrooms. The program creates partners between the teachers and the closest of four participating universities: Tufts University, the University of Massachusetts at Lowell, the University of Massachusetts at Amherst, and Worcester Polytechnic Institute.

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In addition to introducing the design process as a concept, the program also aims to utilize this process as an opportunity to connect the content areas in science, math and technology. Teachers representing all of these disciplines attend the PCET professional development workshop. In the course of the workshop, they learn about the engineering design process, how it fits with the state curricula [2], and how it can be applied in the classroom. Mentor teachers attend the two week long Tuft Engineering Mentor Institute (TEMI) workshop which focuses on application to specific grade levels. In the summer of 2003, high school teachers attended TEMI, and in the summer of 2004, middle school teachers attended a similarly formatted workshop. During the academic year following TEMI, the teachers are supported by a graduate student and faculty member from their partner university. This support is used to help the teachers as they implement the engineering concepts and complete design projects with students in at least one of their classes. Often, the support also includes short activities and presentations to the students on the scope of engineering and its application in day-to-day life.

The Mentor teachers must also participate in further dissemination of the content and classroom applications to additional teachers from their local area through Satellite workshops. This approach exponentially increases the reach of the program by leveraging knowledge transfer through existing participants in the program. The Mentor teachers from each school comprise a diversified team of math, science, and technology education educators, who bring with them the breadth of knowledge and experience needed to complement and enhance the goals and objectives of the workshops.

First Year Evaluation

After a two-week introductory workshop held in the summer, the first cohort of mentor teachers is expected to return to their classrooms in the fall with the goal of completing at least one engineering design project with their students. Each university provides faculty and graduate student support to the mentor teachers throughout the school year, and then assists them in planning a satellite workshop for local teachers. The graduate students are committed to working 10 hours per week supporting the mentor teachers, for a total of approximately 2 hours per teacher per week. The satellite programs are held at each of the participating universities and made available to local teachers from the same grade level as the mentor teachers. The mentor teachers then provide mentoring support to the teachers who attend the satellite workshop throughout the school year, as this second group of teachers integrates the engineering design process in their classrooms.

The PECT program was launched in the summer of 2003, when twenty-two high school teachers from nine high schools across the state of Massachusetts participated in TEMI, the two-week professional development workshop held at Tufts University. During the school year, the teachers integrated engineering in their math, science, or technology classes, and began planning a summer satellite workshop with their partner university. The summer satellite programs ran concurrently with the start of the second cohort of teachers, who taught middle school science, math, and technology classes. This second group of master teachers is spending the current

school year integrating the engineering design process into their classrooms, and will in turn plan a satellite workshop for local middle school teachers for the summer of 2005. Also in 2005, the third cohort will start the PCET TEMI program, which will consist of upper elementary school teachers, grades 3-5. In 2006, the final cohort of mentor teachers will start the program, and will be comprised of lower elementary school teachers, grades K-2. The PCET program extends to 2007, when the final K-2 satellite program will have been completed.

Surveys were distributed in the fall of 2004 to assess the effectiveness of the PCET program among the first cohort of mentor teachers. The survey was designed to assess the teachers' knowledge of and comfort with teaching engineering as a result of the summer TEMI and satellite programs on a 1 to 10 scale, with 1 being 'not at all knowledgeable' and 10 being 'very knowledgeable.' Table 1 presents the 'average before PCET', 'average after PCET', and 'average change' in knowledge of and comfort with teaching engineering for the 15 teachers who completed the survey. As a whole, the teachers reported that their knowledge of engineering and comfort with teaching it significantly increased as a result of the PCET program. The survey also reported that all of the responding teachers are integrating engineering into their math, science, or technology classrooms for the second year in a row, even though they are no longer required to do so.

Table 1: Teachers Assessment of Their Engineering Knowledge and Comfort Due to PCET

Avg. Before	Avg. After	Avg. Change	Evaluated Tasks and Topics
4.2	7.9	3.4	Massachusetts State Science and Technology/Engineering Standards
4.1	8.4	4.3	Integrating engineering into science and math classrooms
3.9	7.9	4.1	Determining the relevant design features in a building project
3.4	9.1	5.6	The engineering design process
3.9	8.4	4.4	The types of considerations that must be taken into account when evaluating an engineering solution
4	8.3	4.3	Designing engineering projects for the courses you teach
3.7	8.6	4.9	Implementing engineering projects in the classroom
3.7	7.7	3.9	Answering students' engineering-related questions
4.7	8.5	3.9	Assessing students' engineering projects
4.5	8.6	4.1	Talking about engineering concepts

The High School Satellites

The Satellite workshops were developed by the mentor teachers, who reviewed the TEMI workshop materials and modified the schedule and contents to make them appropriate for re-delivery during the Satellite workshops. In several of the high school level Satellite programs, the structure was modified from that of the TEMI workshop so that more time was allocated to

project based learning, as opposed to lecture based learning. Additionally, more time was provided for the teachers to discuss what they were learning, to work on their projects, and to complete homework assignments. This timing varied depending on the program The way in which the engineering design process was taught also varied from group to group. For example, one group chose to designate an hour each day to analyze each step in the engineering design process, while another group decided to explain the entire process in a single day. In all of the satellite programs, mentor teachers were responsible for making presentations on how they implemented the engineering design process into their classrooms. This allowed the Satellite participants the opportunity to interact with and learn from colleagues who had already begun integration of the design process. Each Satellite program was designed by the mentor teachers to improve upon the presentation of the professional development content and to incorporate lessons learned through the integration of the engineering design process into the classroom. Each Satellite program was given this flexibility, and consequently the four satellite programs differed from each other and from the original workshop.

The UMass Amherst Satellite program was very similar to the original Tufts workshop, with the exception of several items. While the mentor teachers had enjoyed the lectures on various disciplines of engineering, they felt that a project-based program would be more valuable. Consequently, the Satellite teachers were introduced to engineering by a short presentation that provided a generalized view of different disciplines of engineering and then sat in on only three lectures on assistive technology, wind power, and environmental engineering. While the original PCET program was focused on two areas of engineering, water treatment and assistive technology, the UMass Amherst workshop added a third area: alternative energy. This was added to give more diversity to the program, and to demonstrate an additional field of engineering to the Satellite teachers. Another key difference between the original program and the UMass Amherst Satellite was the incorporation of nightly readings. The purpose of the assigned reading was to cover material not necessarily discussed during the workshop. Topics of these readings included brainstorming, technological literacy and viewing children as natural engineers.

During the UMass Amherst and WPI Satellite workshops, all of the Mentor teachers from the partnership were responsible for making presentations. These presentations primarily focused on the engineering design process and how it fit into their classroom during the year. The Mentor teachers were also responsible for running several of the mini design projects and follow-up discussions on how the design projects could be used in the classroom.

Over the course of the academic year following the Satellite workshops, the Mentor teachers and satellite teacher participants are required to participate in a minimum of eight contact hours. Since the Satellite teachers do not have the benefit of university support, these meetings allow the teachers to share discuss problems as well successes they may be having with implementation of the engineering design process. Groups of mentor teachers and satellite participants chose to set up the partnership differently. Three of the groups chose to assign mentors to specific Satellite participants, allowing them to choose meeting times convenient to them. The final group decided to hold monthly meetings where teachers could choose which

meetings they wanted to attend based on date, location, and topic of discussion for the meeting. The hope for this set-up was that Satellite teachers might have the opportunity to also interact with their fellow satellite participants as well as their Mentors. The success of the partnerships will be evaluated after the conclusion of the 2004-2005 school year. Some of the topics of discussion for these meetings thus far have been "Fitting engineering into the timeline: conflicts with integrating long projects into a limited time-frame", "Increasing student awareness of alternative energy", and "Teaching heat and energy efficiency through design".

A wide variety of projects will be integrated into classrooms this year as a result of the satellite programs. One general science teacher will be using the engineering design process to have her students build boats made of household materials, and will be testing them for floatability, seaworthiness, and cargo capacity. A high school math teacher will have his senior calculus class build catapults and make the appropriate trajectory calculations to have their payload land in a set area. Another class is creating timing devices that require precise measurement accuracy.

Second Year Evaluation

Twenty-three middle school teachers in the math, science, and technology disciplines participated in the Tufts TEMI workshop in the summer of 2004, representing twelve middle schools in eight school districts in central and eastern Massachusetts. Six of these school districts were also represented during the previous year by teams in the high school TEMI workshop. This continuity will help with systemic change within those districts. The representation of teachers and the course topic areas taught by this group consisted of five from math, thirteen from science, and five from technology.

Success at the middle school level is instrumental to the PCET program, because the Engineering/Technology portion of the MCAS exam has been implemented with testing in grades five and eight. It is in these grades that, in accordance with the Massachusetts Curriculum Frameworks, students are first exposed to engineering design as a defined process, and are expected to apply it to solve problems. For this reason, it is important to create widespread knowledge of the process and its application in different disciplines among middle school teachers. The PCET program was designed to involve teams of teachers in pioneering or refining engineering design activities and projects with the intent that they may work with each other on projects and serve as resources to their colleagues.

The structure of the TEMI middle school workshop was very similar to that of the high school workshop held the previous summer. It included lectures, discussions, activities, field trips and projects all designed to both expose the participants to a variety of engineering disciplines and to broaden their knowledge of the engineering design process[4]. As in the high school TEMI workshop, two larger projects were completed by the teachers dealing with assistive technology and water filtration. As with the high school mentor teachers, each middle school mentor teacher was responsible for implementing the engineering design process into their classrooms through completion of project work during the following academic year.

Although the structure of the middle school program was similar to that of the high school program, the content differed somewhat to incorporate feedback from high school participants. Aside from the adjusted content level to make activities more suited to middle school curricula, teachers in the program took a more active role in sharing engineering related projects that they had completed previously with their classes. Several of the TEMI teachers from the high school level lead activities with the middle school teachers and spoke about their experiences with the program. Activities such as RoboLab programming and conceptual exercises were added to the middle school workshop to present an even more diversified view of engineering than was given the previous year. As per suggestions from high school TEMI participants, teachers were also given more time to discuss the design process and implementation with each other.

Prior to their participation in the PCET program, a greater number of middle school TEMI teachers had already utilized project work as a method for introducing their students to engineering and design as opposed to high school mentors. The middle school teachers also worked more on refining the way in which they presented the design process rather than inventing new projects. It is partly due to this level of effort and previous experience that fewer of these teachers chose to use the projects presented during the workshop in their classrooms. Instead, they re-adapted existing items from their curriculum. This allowed teachers the benefit of more time to share their experiences with others in the program.

The feedback from the middle school mentor teachers and their students has been positive. At this point in time, over half of the teachers have completed at least one engineering project with their students. Some of the projects that are currently in progress or have been completed this fall by the middle school TEMI teachers include roller coaster design, exploring the history of modern inventions and design of a medicine container that must travel through the jungle and keep the medicine cool. Many of the teachers have also chosen to use short labs and activities to introduce engineering. These have ranged from exploring the mechanics of a click pen to design of adaptive sports for people with disabilities. Many schools in Massachusetts have recently been placing a greater emphasis on technological literacy, and some of the PCET teachers in these schools at the middle as well as high school level have used this as an opportunity to introduce the design process and to expose the students to different disciplines of engineering.

Conclusion

The PCET program has been running for two and a half years and the impact has been significant. Forty-five mentor teachers have participated in the two-week TEMI summer workshops. They in turn have completed engineering based projects with a minimum of 1,125 students, assuming an average class size of twenty-five. This number takes into account each teacher having completed a project with a single class, which is the minimum requirement. Although it has not been documented past the required level, many of the teachers have shared that they have completed a single project with multiple classes, and some have completed multiple projects. The high school Mentor teachers have reported that they continue to integrate engineering into their classes, even though it is no longer required to do so. These Mentor

teachers also participated in the development and delivery of four Satellite workshops for high school teachers. Ninety-six teachers attended the Satellite workshops and these teachers are in turn are completing engineering projects with a minimum of 2,400 students. Feedback from the high school Mentor teachers indicates that their overall knowledge of engineering and comfort with teaching engineering projects has increased significantly since the start of the program.

Judging from the success of PCET at the high school level as well as the positive feedback from teachers and students regarding the projects implemented thus far at the middle school level, it is the hope of all involved that the focus on the engineering design process through this program will improve not only student scores on the upcoming spring MCAS engineering/technology exam, but will refine their problem solving skills to be employed in higher education and in life.

The numbers of teachers and students reached with the PCET program beyond the initial impact of the first years of the program are shown in Table 2. In this second year, our first set of mentor teachers continue to do engineering projects with the current year of high school students impacting at least another 1,125 students. At the end of this year, our cumulative impact will be 141 teachers and at least 4,675 students.

Table 2: Cumulative Impact of the PCET program per year

	June 03-May 04	June 04 – May 05	June 05 – May 06	June 06 – May 07	June 07 – May 08
mentor teachers	23	22	24	24	
satellite teachers		96	96	96	96
mentor students	575	1,700	3,425	5,750	8,075
satellite students		2,400	7,200	14,400	24,000

Over the next three years, the PCET program will be holding two more TEMI summer institutes and three more Satellite programs, reaching a total of approximately 336 teachers. Assuming that each teacher has 25 students per class, and that the teachers continue to use engineering projects with at least one class per year, by the end of the program over 32,000 students will have been introduced to the engineering design process as a direct result of the PCET program.

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