2006-1796: ENGINEERING AT THE ELEMENTARY LEVEL - DOES TEACHER TEAM SIZE IMPACT EFFECTIVENESS?

Martha Cyr, Worcester Polytechnic Institute

Martha Cyr is the director of K-12 outreach and an adjunct professor with the Mechanical Engineering Department at Worcester Polytechnic Institute in Worcester, Massachusetts. Her main area of interest is effective engineering education for all ages. Dr. Cyr received her B.S. in Mechanical Engineering from the University of New Hampshire in 1982, and her M.S. and Ph. D. in Mechanical Engineering from Worcester Polytechnic Institute in 1987 and 1997.

Sean Doherty, Worcester Polytechnic Institute

Sean Doherty is a graduate fellow of the PCET program. He is currently seeking a Masters degree in Computer Science at Worcester Polytechnic Institute in Worcester, Massachusetts. His main area of interest is applying Artificial Intelligence techniques to solve real-world problems. Sean received his B.S. in Computer Science from Worcester Polytechnic Institute in 2005. Sean graduated with highest distinction and is a member of Tau Beta Pi and Upslion Pi Epsilon.

Shweta Shanbhag, Worcester Polytechnic Institute

Shweta Shanbhag is a graduate fellow of the PCET program and is a second year graduate student in Biomedical Engineering at Worcester Polytechnic Institute, Massachusetts. Her main interests lie in Medical Imaging techniques to successfully differentiate between viable and necrotic tissue. Shweta received her B.E. in Biomedical Engineering from D.J.Sanghvi College of Engineering, Mumbai, India,2004.

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Abstract

Teachers are often asked or required to introduce their students to concepts and content that the teacher does not have a background or training in. Pre-engineering concepts certainly fall within this list of things for elementary teachers. As part of our program to help teachers learn the necessary content to do engineering design activities in their classrooms, we also assessed the impact of teacher team size. Some of the things we considered are: if a team of teachers attends the workshop to learn the content, are they more effective implementing it than teachers who did not attend the workshop as part of a team? Does the size of a team make a difference? This paper discusses how the content is presented, and measured results for varying size teams.

Introduction

In 1993, the Massachusetts legislature passed the Education Reform Act, which called for the creation of curriculum frameworks [1] or guidelines for what should be taught in all schools at different grade levels. This law also called for a "comprehensive assessment system" that for each school would measure whether students could demonstrate competency in four subject areas. These subjects are Mathematics, English/Language Arts, History and Social Studies, and Science & Technology/Engineering. Consequently, a single integrated test called the 'MCAS' or the Massachusetts Comprehensive Assessment System was introduced to drive the students and teachers to improve upon the quality of education and student learning. This test is now administered at the elementary, middle and high school level, with 25% of the 5th and 8th grade level science test addressing technology/engineering learning standards.

With the set of state wide tests in place, and a lack of teacher expertise in implementing the technology/engineering standards, there arose a need to assist the teachers in this area. An attempt to address this demand led to the introduction of the Pre-College Engineering for Teachers (PCET) program by Tufts University with a grant from the National Science Foundation [2]. The primary goals of this program are to familiarize the participating teachers with the engineering design process, to introduce them to an assortment of projects to enhance learning and to incorporate engineering principles in their curriculum. Starting in 2002, this program has already been implemented at the high school and middle school levels and is now in progress at the elementary school level. Table 1 shows the progression of the program implementation and the grade levels of participating teachers.

Implementation

How it works: Each summer of program since 2004 there are two sets of teachers who participate in PCET workshops. A set of 24 Mentor teachers who are all from the same grade band (eg. 3-5 or middle school), attend a Tufts Engineering Mentor Institute (TEMI) workshop. Concurrently at Tufts University and the partnering institution sites of Worcester Polytechnic Institute and

University of Massachusetts Lowell, PCET satellite workshops are run by the previous year's mentor teachers and participating engineering graduate students. The satellite workshops are for local teachers to attend and learn the same concepts that the TEMI teachers learned – primarily about the engineering design process and implementation of engineering principles in the classroom. In both cases the workshops provide 80 hours of instruction and activity time.

Table 1: Implementation Schedule and Impact

	Summer 2003	**Summer 2004**	**Summer 2005**	**Summer 2006**	**Summer 2007**
High School	TEMI - Tufts	PCET -Tufts, UML, WPI			
Middle School		TEMI at Tufts	PCET- Tufts, UML, WPI		
Elementary: 3-5			TEMI at Tufts	PCET - Tufts, UML, WPI	
Elementary: 1-2				TEMI at Tufts	PCET - Tufts, UML, WPI
# of teachers	22 teachers	118 teachers	120 teachers	120 teachers	96 teachers

During the summer of 2005, 22 elementary school teachers from 7 elementary schools participated in the TEMI workshop at Tufts University along with 4 graduate students; one from Tufts, two from WPI and one from University of Massachusetts Lowell. In order to provide proper support during the year, the teachers were divided into three groups depending upon their proximity to the graduate fellows they had been assigned. WPI had an opportunity to assist 10 teachers, six of which teach at Edward Hopkins Elementary School in Hopkinton, two at Heritage Elementary School in Charlton and two at Woodrow Wilson Elementary School in Framingham.

Curriculum: Over the course of the workshop the 22 elementary teachers were introduced to five projects which they were asked to incorporate in their curriculum the following year. Each of the five projects introduced to the mentor teachers complies with the Massachusetts curriculum frameworks [1] with a particular emphasis on the Science & Technology/Engineering standards, and are part of the Engineering is Elementary [3] materials. Engineering is Elementary (EiE) combines elementary level technology and engineering with commonly taught science lessons through a storybook whose main character is a child that works on solving a real world problem. For each unit the materials introduce the students to an engineering field and leads them through a simplified design process using a five step approach (shown in Figure 1) of "Ask, Imagine, Plan, Create, Improve" as they work to solve the same problem as the character in the story. The selected projects used for the TEMI workshop were:

- Water Purification (civil engineering), in which the students design and test a water filtration system,
- Wind (mechanical engineering), for which students design and test a windmill,

- Insects (agricultural engineering), which has the student design a hand pollinator for a different flower shapes,
- Walls (materials engineering), that has students combining materials to design and make bricks for a wall that is tested for strength, and
- Simple Machines (industrial engineering), for which students combine multiple simple machines to design and test a subsystem for a factory.

The teachers select one or more of these projects to implement in their classrooms. With in-class help from the graduate students at the partnering institutions, the teachers went over the 5 basic steps of the design process with the students, helping them to get a stronger sense of engineering and science through hands on experience. Using this process, the ostensibly exacting concepts of engineering were easily understood and clearly grasped by the students according to the not only the feedback from the teachers, but also from the observed student feedback in the classroom. Giving them the chance to build their own designs, see the reasons for failure and redesign accordingly provided a real world application that helped students to solidify the concepts.

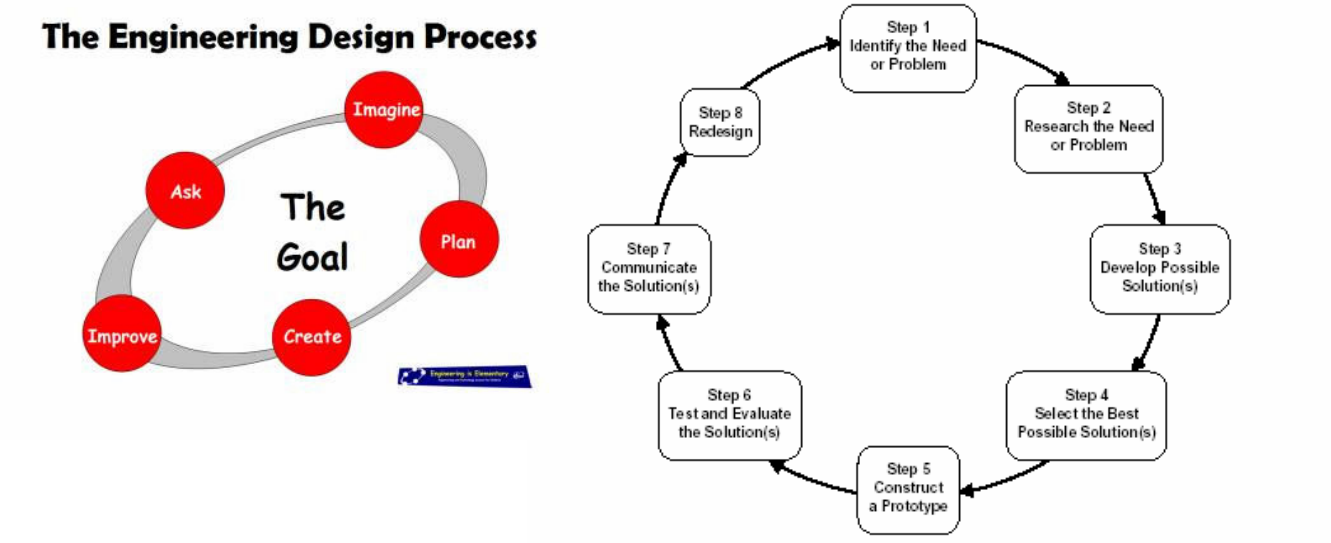

Figure 1
Schematics of the Engineering is Elementary 5 Step Design Process and the
Full 8 Step Design Process from the MA Curriculum Frameworks.

Assessment

Since PCET is a 5-year program, we use formative evaluations to modify it each year based on the observations and results in the past years so as to improve it continually. Our main aim in the program is to reach out to teachers and promote out-of-the-box learning methods to encourage scientific thinking in their students: for them not just to learn the project-based techniques, but also to successfully implement them in their classrooms.

In 2003, when the program was initiated with high school teachers, 22 teachers from nine schools were introduced to the detailed 8-step design process through activities in water-treatment and assistive technology [4]. These 8-steps come from the MA curriculum framework and are "Identify the need or problem, Research the need or problem, Develop possible solutions, Select best solution(s), Construct a prototype, Test and Evaluate, Communicate the solution, and Redesign," as shown in Figure 1. Although the concept of the design process was similar, the content of the original TEMI workshop and the one for grade 3-5 teachers was quite different.

Overall the TEMI workshop is still an amalgamation of short activities, presentations, guest lectures by engineers, discussions and field trips. However it has been modified over the years to provide grade level appropriate activities that encourage project-based learning. In the first two years no prescribed materials were used. Instead the teachers selected engineering based projects that matched topics or units they already taught. For the elementary level we introduced a more fully developed set of materials with the Engineering is Elementary, and asked for teachers to select from this smaller set for what they would implement in their classrooms. Each year the mentor and satellite teachers are asked for their comments and feedback and information about how the implementation has gone in their classes. This year we observed a diverse crowd consisting of teachers who were familiar with the PCET program due to implementation by one of their colleagues at a different level, teachers who would be the first ones to try these novel teaching techniques at their schools, teachers who worked in groups, and teachers who worked alone. Therefore, we decided to make a few observations and try and find out if the setting under which the teachers worked had any impact at all on the implementation success.

Observations

As of March 2006, six out of the 10 mentor teachers working with WPI had already implemented at least one project in their classrooms. Due to the immense popularity with the students, most of these teachers were very enthusiastic about doing at least one more activity with their students, although they had been asked to implement only one of the five projects from the summer. During the academic year we tried to observe and record a few things such as:

- What kind of teaching models worked best?
- If the teacher group size affected the implementation of the projects?
- Under what circumstances did the teachers seem most enthusiastic upon implementing what they learned over the summer?
- Did they think the project based techniques helped them get their point across faster without intimidating the students about 'engineering principles'?

Our observations of the impact of the size of a teaching team upon effectiveness with the Engineering is Elementary curriculum were mostly gathered through discussions with teachers before and after class. In order to get quantifiable results, we also distributed a survey to the teachers to gauge their feelings. This survey gauged the teacher's feelings about teaching the engineering lessons prior to the actual instruction in the class setting. We also tried to ascertain the reason for their comfort or their lack of comfort in teaching these lessons before and after teaching them, as well as the reason their comfort level changed. Since our goal is to determine the impact of team teaching on the effectiveness of the lessons, the survey also allowed the

teachers to explain how they think that team teaching will or would possibly affect their teaching effectiveness.

Most of the teachers have commented that because of the schedules and short class times that these lessons have been a challenge to fit within their allotted time. With this being the case for most schools, the teachers who were team-teaching responded on their surveys that the teams helped greatly with time management. Many teachers who were team-teaching commented that they were able to have more student interaction because of other team members helping them with the administrative tasks. Since things such as passing out materials and making sure that everyone is in the proper group happened more quickly it allowed the teachers to spend more time personally instructing the students and helping them to understand what they were doing during the lesson.

Teachers who were part of a team said that the ability to share materials and prepare things together freed up time to spend on planning the lessons. Team-teaching not only helped in this way, but also in other, smaller ways. For example, one team of teachers wanted to make the groups in their classes smaller in order to increase the effectiveness of the lesson through more hands on time for the students. A lack of a key material (rubber stoppers for test tubes) was going to force them to have larger group sizes. A donation of this key material from a parent to one of the teachers was shared among all, allowing the teachers to lower the group sizes.

When the teachers shared their thoughts on team-teaching, many of them stressed that the ability to work together allows them to talk through the lessons with other teachers. This mutual planning time led many of the teachers to come up with new ideas for the lessons as well as being able to identify problem areas in the lesson. One of the teachers who is not team-teaching said: “Having someone else’s view might help in seeing a problem with the students not getting the lesson. When you are by yourself you could get stuck and not know how to correct it.” Along with identifying these problems, teachers who are not team-teaching feel like working with others could help ease the burden on themselves. One teacher said: “If I could I would rather teach the lessons with at least one other teacher. It’s been very hard for me to do all of this alone.” The quotes from these two teachers demonstrate some of the issues faced by teacher working alone. In contrast to this, we have observed our team-teachers working together not only on improving the existing lessons, but also creating new lessons that build off of the curriculum presented through this program. In this way, the team-teachers seem to be thriving in their situations while the teachers who are alone seem to be frustrated with their ability to implement the Engineering is Elementary lessons.

This set of teachers commented that team teaching also allowed them to share some of the tips and techniques they had learned during the course of preparing and doing the lessons – such as what group size worked well and how best to prepare the materials for the students. One teacher, when speaking about the effect of team-teaching, commented that “it also helps to share successes with one another and learn from each other’s mistakes.” This shows how the idea of team-teaching has allowed these teachers to be better equipped by learning about effective lesson presentation from other practitioners, rather than just following the on-paper directions. By saving these teachers from the same mistakes that their team-teachers made, we feel that teaching as a team has increased their effectiveness.

Our focus when assessing our observations falls under 3 main categories: teacher confidence, teacher preparedness and teacher effectiveness. Since the last of these categories can often be viewed subjectively, we relied upon our own observations and teacher feedback as to how the students responded to the curriculum. It was not our goal to provide informative results through testing the students on material to show improvement in their learning. Instead this grant addresses the teachers' confidence and knowledge for presenting the engineering lessons to their students.

Due to the similar nature of the Engineering is Elementary units we are eliminating the variability in teaching effectiveness that might come with varying topics. It is our hope that we will see a clear distinction in the results between our teachers who are teaching these lessons by themselves and those who are teaching in a team environment. The varying personalities within our testing group, which may or may not hinder their ability to teach within the "team-teaching" model, are not included in our results. Teachers who have long been accustomed to working alone often find it hard to rely upon another teacher for their expertise. We have seen that while this is the case in a wide range of teachers, it tends to occur more often within the older generation of teachers. These results will be most pertinent to our discussion, because we expect to see these teachers who have not taught previously in a "team-teaching" manner experience a significant rise in each of our assessment categories.

One of the other observations we made was that the teachers developed confidence in teaching topics related to science and technology/engineering. Most of the teachers who attended the TEMI workshop had minimal knowledge about topics in engineering and some of them admitted were very intimidated by the concept of teaching it. As the workshop progressed, the teachers gained hands on experience with the content. This allowed their own understanding of science and engineering to grow and their apprehension about engineering lessened giving way to genuine interest and curiosity. Most of them believe that their own added enthusiasm in the topic has assisted them to help their students learn better.

Most importantly however is the impact on the students. We anticipate that those teachers who work in a "team-teaching" model will have greater confidence with the material which in turn will allow them to feel more able to go beyond the basic curriculum and provide a richer experience for the students. Within the context of the engineering lessons, we foresee this taking shape through the teachers asking students questions such as "why do you think that happened" or "what do you think that means". Questions like this get the students to think critically and truly be able to "own" their knowledge, rather than being told to memorize terms or concepts. This is where the practical applications of assessment categories most show through in the classroom.

Results:

In our pre-survey we interviewed 18 elementary school teachers to see if they thought that working in a team was more effective for implementing the concepts they learned in the summer workshop. Our results are shown in Table 2.

Table 2: Pre-survey Results

	Positive Responses	
	Team-Teaching	Teaching Alone
Teacher who thought that the had benefited or would benefit from team-teaching	100%	90%
Teachers who felt **very comfortable** with teaching the lessons	50%	66%
Teachers who felt **fairly comfortable** with teaching the lessons	38%	22%
Teachers who **did not feel comfortable** with teaching the lessons	12%	12%
Teachers who saw a majority of their confidence come from teaching alone or as a team	57%	38%

A few interesting results are:

- Out of the 18 teachers only 1 believed that team teaching would not help
- Of all the teachers who were team-teaching,
  - 12% thought they would not be comfortable teaching the engineering lessons in their classrooms
  - 38% thought they were fairly comfortable teaching the engineering lessons in their classrooms and
  - 50% thought they were very confident teaching the engineering lessons in their classrooms
- All but one of the teachers who were not team-teaching believed that team-teaching would be beneficial for them in implementing engineering lessons in their classrooms.
- Even though the team-teachers as a whole seemed less confident with the material, 57% of these teachers drew most of their confidence from team-teaching.

The end of year survey will provide additional results about understanding of the impact of team teaching. This survey will allow the teachers to debrief on how the students performed after the lessons as well as how they responded during and immediately after the lessons were presented. Data from the end of year survey will be included in the conference presentation.

Conclusion

In conclusion, based on the results we obtained to date, we have seen that teachers who were already working in a "team-teaching" model had greater confidence, preparation and effectiveness in the classroom. This indicates that teachers who have other teachers to prepare with, bounce ideas off, and more generally give tips that worked for them, will succeed more than those who are "going it alone". Also observed is that the teachers who are currently working alone think that having a team teacher to work with would assist them with the implementation of their lessons. This result was clearly shown in our pre-survey, in which all but one teacher who was not team-teaching thought that they would benefit by teaching as part of a team. Our

final survey will show the results of team-teaching vs. teaching individually from an end of the year perspective. Based on the mid program results it is anticipated that the end of year results will show how teachers who are able to "team up" with teachers in their building become more effective at their jobs than if they teach independently.

The next step of this research will be to do the same assessment with teachers who participate in the satellite program for PCET in the 2006-2007 school years. Since this will be a set of approximately 48 teachers the outcome will provide strong information about whether professional development is better for the students (and teachers) if the teachers participate in teams. We feel that this will not only aid in the effectiveness how to deliver materials such as the Engineering is Elementary (EiE) curriculum, but also help to encourage the teachers to try this model in other subject areas. This next step will not only validate our results, but also be a step towards proving that this teaching model works extremely well with engineering curriculum.

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