AC 2009-1281: PUTTING THE 'E' INTO STEM EDUCATION IN THE ELEMENTARY SCHOOL

Michael Pelletier, Northern Essex Community College

Linda Desjardins, Northern Essex Community College

Paul Chanley, Northern Essex Community College

Lori Heymans, Northern Essex Community College

Putting the 'E' into STEM Education in the Elementary School

Abstract:

During the summer of 2008, in year one of a three-year project funded by the Massachusetts Pipeline Fund and entitled "STEM ROCKS," a cooperative effort began to introduce *Engineering is Elementary* into the elementary schools of four public school systems in Massachusetts. Twenty-two teachers drawn from the four school districts worked with eight community college professors of engineering, mathematics, and science from two community colleges to form a cadre of trainers who would lead the professional development of another one hundred and eighty four teachers.

The teachers and professors attended a three-day Teacher Educator Institute and then attended a series of day-long workshops at one of the community colleges to develop plans for the most effective way to introduce a unit of *Engineering is Elementary* into the classrooms of each of the twenty-two elementary school teachers. Each selected unit had to fit with the unique curriculum of each elementary school. The community college faculty provided help with the engineering, science, and mathematics concepts needed to support and supplement the units of *Engineering is Elementary.*

The teachers were also asked to develop with the assistance of the community college faculty an appropriate plan for the professional development of their elementary school colleagues over the next year and to present the plans to the districts.

An outside evaluator was employed to gather and evaluate data and report the results of the summer's activities. His findings are included.

Introduction

In 2003, by act of the Massachusetts legislature, in an effort to increase the number of students choosing STEM (Science, Technology, Engineering, and Mathematics) careers, a STEM Pipeline Fund of $2.5 million was established within the Economic Stimulus Trust Fund. The STEM Pipeline Fund was recapitalized in 2006 with an additional $4 million as part of economic stimulus legislation.

The purposes of the STEM Pipeline Fund are to increase the number of Massachusetts students who participate in programs that support careers in fields related to science, technology, engineering and mathematics, to increase the number of qualified STEM teachers, and to improve the STEM educational offerings available in public and private schools.

To promote these purposes, the STEM Pipeline Fund has funded seven regional networks across the state. One of these regional networks is the Northeast Regional Pipeline partnership. The members of the Northeast Regional Pipeline Partnership include fourteen public school districts, several charter schools, two private four-year colleges, one public four-year college, three community colleges including Northern Essex Community College and Middlesex Community College, the University of Massachusetts Lowell, eight businesses and organizations, and the Workforce Investment Boards of the Northeast Region. The University of Massachusetts Lowell has been the lead partner of the Northeast Regional Pipeline Partnership.

Description of Decision-Making Process to Arrive at Proposal

In November of 2007, a meeting of the Northeast Network STEM Advisory Council was held at Middlesex Community College. Participants were briefed on the Request for Proposals from the STEM Pipeline Fund entitled, "Enhancing Student Interest and Retention in STEM Fields." Proposals could be for up to three years in duration. The purpose and goals of the RFP were discussed and a timeline and an outreach plan were developed, encouraging public and private schools in the region to identify their needs and opt into the proposal to the Pipeline Fund.

The RFP was focused on the first STEM Pipeline goal of increasing the number of students who pursue careers in STEM subjects and was seeking proposals which increased STEM awareness and /or STEM learning and which were focused on elementary and middle school grades. The RFP cited research which demonstrated that perceptions of academic ability, occupational awareness, and gender stereotypes are strongly developed during the late elementary and middle school years as a prime reason that proposals aimed at elementary and middle school students were being sought.

At the suggestion of the University of Massachusetts Lowell, it was agreed that a community college partner would be the lead on this proposal. Northern Essex Community College agreed to be the lead partner and Middlesex Community College gave its full support to this arrangement.

There was widespread agreement among the partners about major problems facing elementary schools, (oftentimes, teachers most comfortable in language arts were asked to teach every subject including all STEM disciplines), and the statewide Grade 5 tests in Science and Technology/Engineering were putting real pressure on schools to raise students' scores. But, unfortunately, schools lacked the resources needed to do this effectively.

The statewide Grade 5 test in Science and Technology/Engineering is based upon the current Massachusetts Science and Technology/Engineering Curriculum Framework which specifies learning standards for Grades 3-5 in Technology/Engineering in addition to Earth and Space Science, Life Science (Biology), and Physical Sciences (Chemistry and Physics). The learning standards for Grades 3-5 in Technology/Engineering (see appendix)[1] speak of elementary school students being able to use Engineering Design to solve problems as well as use appropriate materials and tools.

Elementary school teachers were reported by their administrators to be most comfortable with the life sciences and least with the physical sciences and largely ignorant of engineers and engineering design.

Moreover, at both the elementary school and middle school levels, there was perceived to be a lack of awareness of STEM fields and careers and their importance.

Following that meeting, an e-mail was sent to the Northeast Network partners asking them to bring a list of "best practices" STEM programs for students in upper elementary and middle schools to the next meeting of the Advisory Council. At this next meeting, the Advisory Council members decided to concentrate on in-school programs for the elementary school students, as opposed to after school programs.

It was agreed that units from the Engineering is Elementary (EiE) program[2], developed by the Museum of Science[3], along with the science and math concepts associated with the units would be used. Through Project ATLAS the Engineering Science faculty and the Education faculty at Northern Essex Community College were already collaborating with the Museum of Science on using EiE to bring an awareness of engineering to pre-service education students at the community college. It was recognized early on that three years would be the minimum time required for this project which would begin in the spring of 2008 and continue until the spring of 2011. The goal of this project would be to successfully introduce EiE into every classroom of all three grades (3, 4, and 5) of every elementary school within each participating school district.

Once the activities of the project were established, all of the partnering schools in the Northeast Network were contacted and offered the opportunity to participate. Billerica, Chelmsford, Methuen, and Reading asked to join the Engineering is Elementary initiative.

When the grant awards were announced, STEM ROCKS received less money than had been requested in the proposal. The length of the grant was three years, beginning in April, 2008. The reduction in funds which had been requested for EiE made it necessary to scale back the original goal of teaching EiE in every classroom of each of the three grades (3, 4, and 5) of each elementary school in the four participating districts. The revised target would be to teach EiE in every classroom of two of the three grades (3, 4, and 5) of each elementary school in the four participating districts. The decision on which two grades would be chosen was left up to each school district.

Project Description

STEM ROCKS, funded as a student interest project, seeks to win hearts and minds in the elementary schools and to put the "T" and "E" (technology and engineering) back into STEM while emphasizing the supporting science and mathematics.

The principal aim of STEM ROCKS is to introduce EiE into every classroom of two grades of each elementary school in Billerica, Chelmsford, Methuen, and Reading. A much smaller part of STEM ROCKS also introduces information technology (IT) and careers in IT to middle-school-aged Latin girls through Viva Computing for Latinas, an after school program at the Lawrence Boys and Girls Club. Another after-school program aimed at middle-school-aged girls, entitled GEMS (Girls Experiencing Math and Science), is funded by STEM ROCKS and conducted by Middlesex Community College.

EiE is meant to be integrated with a school's existing science and mathematics curriculum. For example, simple machine concepts such as levers, inclined planes and pulleys, are traditionally introduced in 4th or 5th grade of elementary school. These concepts will still be covered in science class but enhanced through the implementation of the Marvelous Machines Unit of EiE. The EiE module will allow the teacher to introduce the science fundamentals and then apply the engineering design process to demonstrate the application of simple machines. Teachers can reinforce science concepts by showing where the concepts are used. The different science curriculums used in the four elementary school systems of STEM ROCKS often cover the same science topic in different grades which explains why the same unit of EiE will be used in different grade levels in the four school systems.

The Teacher's Guide for each unit of EiE contains specific tie-ins with the science concepts of elementary school science curricula such as GEMS, FOSS, and STC as well as a mapping to the Massachusetts Science and Technology/Engineering Standards (see appendix).

The units of EiE selected as most appropriate to each school district's science curriculum, the grade in which the unit will be used and the field of engineering on which the unit focuses are shown in Table I. Each unit of EiE is also adjustable to different ability levels within a grade or a classroom.

Table I: Units of Engineering is Elementary by School System

District	Grade	Engineering is Elementary Unit Title	Engineering Field
Billerica	4	An Alarming Idea: Designing Alarm Circuits	Electrical
Billerica	5	Marvelous Machines: Making Work Easier	Industrial
Chelmsford	4	Marvelous Machines: Making Work Easier	Industrial
Chelmsford	5	An Alarming Idea: Designing Alarm Circuits	Electrical
Methuen	3	The Best of Bugs: Designing Hand Pollinators	Agricultural
Methuen	4	Catching the Wind: Designing Windmills	Mechanical
Reading	3	Catching the Wind: Designing Windmills	Mechanical
Reading	4	Marvelous Machines: Making Work Easier	Industrial

Activities to Achieve Objectives and Timeline

From April, 2008 - June, 2008, Billerica, Chelmsford, Methuen, and Reading public schools identified a total of twenty-two lead teachers, (one teacher from each elementary school in the four districts), to serve as trainers for EiE. Each of the four school systems selected two units of EiE which best fit the curriculum of that school system and the two grades out of the three grades, 3, 4, or 5, in which the units would be used. At the same time each community college selected faculty to participate. Middlesex Community College selected one engineering professor, one information technology professor, and three math professors. Northern Essex Community College selected two engineering professors who also teach college mathematics and a math professor who is a degreed engineer.

From June 30 to July 2, 2008, the thirty trainers, (twenty-two teachers and eight community college faculty), attended a three-day Teacher Educator Institute on Engineering is Elementary at the Museum of Science. The workshop introduced the participants to the nature of engineering and technology, the engineering design process and the interrelationship between science, engineering, technology, and mathematics. Within the workshop were two strands, each focusing on three different units of EiE. Each of the twenty-two teachers participated in the strand which contained the unit he/she would be implementing in his or her classroom in the spring of 2009.

The workshop began with a common first day that introduced the teachers to engineering, technology and the engineering design process by means of the types of hands-on activities the teachers will later use in their own classrooms. Likewise the activities of each strand engaged the participants in activities their students will eventually experience. The teachers participated in the engineering design process using real EiE materials and student hand-outs and experienced for themselves the excitement of creating engineering solutions to real problems.

Participants also received an overview of the curriculum design of EiE. Each unit of EiE contains a preparatory lesson to prompt students to think about engineering, technology, and the engineering design process. Then there are four additional lessons: an illustrated story set in a particular locale that presents a problem facing a young person; a broad view of a particular engineering field personified by an engineer in the young person's life who helps the young person design a solution to the problem; the collection of data related to the problem and the application of scientific and mathematical analysis to the data; and a final engineering design challenge where students use the engineering design process to develop, create, and improve solutions to a problem similar to that faced by the young person in the story.

Table II shows the four units of EiE chosen by the school districts of STEM ROCKS and the science topics, engineering field, storybook and setting related to each unit.

Table II: Units of EiE Related to Science and Engineering Fields

EiE Unit Title	Science Topic	Engineering Field	Storybook (Setting)
Catching the Wind: Designing Windmills	Wind & Weather	Mechanical	Leif Catches the Wind (Denmark)
Marvelous Machines: Making Work Easier	Simple Machines	Industrial	Aisha Makes Work Easier (USA)
The Best of Bugs: Designing Hand Pollinators	Insects/Plants	Agricultural	Mariana Becomes a Butterfly (Dominican Republic)
An Alarming Idea: Designing Alarm Circuits	Electricity	Electrical	A Reminder for Emily (Australia)

Later in the summer, four day-long planning sessions were held, one for each of the four school systems. At these planning sessions the lead teachers and the community college faculty discussed the science and math topics associated with particular units of EiE and ascertained what additional help they would need for successfully implementing the units. They also estimated the number of story books, kits and refills needed for each school system.

The lead teachers from each school system developed lesson plans for each class session detailing how they would teach the chosen unit of EiE in the classroom and when it would be taught during the school year. The preliminary estimate was that the unit of EiE might be taught according to the following schedule, Table III.

Table III: Proposed Schedule for Teaching EiE in the Schools

District	Grade	EiE Unit Title	Sessions	Earliest Start Date
Billerica	4	An Alarming Idea: Designing Alarm Circuits	15	January 5
Billerica	5	Marvelous Machines: Making Work Easier	14	November 15
Chelmsford	4	Marvelous Machines: Making Work Easier	9	December 15
Chelmsford	5	An Alarming Idea: Designing Alarm Circuits	15	January 5
Methuen	3	The Best of Bugs: Designing Hand Pollinators	7	November 15
Methuen	4	Catching the Wind: Designing Windmills	7	November 15
Reading	3	Catching the Wind: Designing Windmills	9	February 15
Reading	4	Marvelous Machines: Making Work Easier	9	February 15

This proposed schedule proved to be overly optimistic; but delays were easily accommodated since the deadline for completing the teaching of all units was May, 2009.

At the same time, the lead teachers and community college faculty developed plans for the professional development of the additional one hundred eighty-four elementary school teachers which will take place over the next two school years. These professional development plans were presented to the administrations of the four school systems at the end of the summer. When the proposal was written, the four school systems had agreed to provide professional development time during the school year for the rest of their elementary school teachers.

Two of four districts decided to have an initial professional development session in the fall to introduce the philosophy and curriculum of EiE to all of the elementary school teachers. All four districts decided to do the bulk of their professional development for the rest of their teachers in the spring after the lead teachers had taught their units in the classroom.

During the fall of 2008, the lead teachers of each school system prepared to introduce the selected units of EiE into their classrooms. During the late summer and fall of 2008, Northern Essex Community College used grant funds to purchase the storybooks, Teacher's Guides, and some of the kits of materials from the Museum of Science. When it was learned that not all the needed kits would be available until February, 2009, Northern Essex Community College also purchased instructional materials directly from suppliers and assembled additional kits.

Beginning with the spring and summer of 2009, another one hundred eighty-four teachers from grades 3-5 in the four school districts will receive professional development in EiE and then will be supported by the lead teachers and the community college faculty as they integrate the unit of EiE into their classrooms over the next two academic years: 2009-2010 and 2010-2011.

Description of Project Evaluation Activities - June, 2008 through January, 2009

Between June, 2008 and January, 2009, five separate evaluation instruments were administered to gather background data concerning the twenty two lead teachers, to determine gains in content knowledge about EiE, to measure participant satisfaction with the Teacher Educator Institute and the planning days held at NECC, and to assess teacher perceptions of engineers and the teaching of engineering design. Details of the evaluation activities from June, 2008, through January, 2009, are provided in Table IV.

Table IV: Project Evaluation Activities - June, 2008 through January, 2009

Activity	Objective(s)	Method of Evaluation	Timeline	Instrument Used	Number of Participants
Teacher Educator Institute & Planning Day at Museum of Science	Introduce Engineering is Elementary to Lead Teachers	Participant Survey	Before June 30	On-line Survey; questions from Donahue Institute[4]	22
Teacher Educator Institute & Planning Day	Introduce Engineering is Elementary to Lead Teachers	Pre-test	Before June 30	On-line Objective multiple-choice test; questions drawn from MoS[5], refined by Project Director and Outside Evaluator	18
Teacher Educator Institute & Planning Day	Introduce Engineering is Elementary to Lead Teachers	Post-test	July 3-31	On-line Objective multiple-choice test; questions drawn from MoS, refined by Project Director and Outside Evaluator	11
Teacher Educator Institute & Planning Day	Introduce Engineering is Elementary to Lead Teachers	Participant Feedback Survey	October 1-8	On-line Survey; questions from Donahue Institute; refined by Outside Evaluator	18
	Teacher Perceptions of Engineers and Teaching DET	Survey	January 5-23, 2009	On-line Survey, questions from Senay Yasar, et. al.[6], refined by Outside Evaluator	17

Description of the Participating Lead Teachers

Before starting the Teacher Educator Institute, each of the twenty-two lead teachers filled out a participant survey. Tables V, VI and VII tabulate the participant survey responses and reflect the number of years the teachers have been employed in education, their educational backgrounds, and reasons for participation respectively.

Table V: Number of Years Employed in Education

Years in Education	3	3.5	4	5	6	7	8	9	10	13	16	17	20
Number of Teachers	3	1	2	2	2	2	2	1	1	1	1	1	1

Table VI: Educational Background of the Lead Teachers

	Subject	Bachelor's Degree	Master's Degree	Doctorate
Degrees currently held	Art	1		
	Education	3	16	
	English Language	3		
	History/Political	2		
	Science	1		
	Special Education	1		
	Health	1		
	Nursing	1		
	Other	4		
Degrees currently being pursued	**Subject**	**Bachelor's Degree**	**Master's Degree**	**Doctorate**
	Education		5	
	Mathematics		1	
	Other	1	1	

The majority of the lead teachers have less than 10 years' experience. Also, all the lead teachers have or are pursuing a master's degree. However, because the majority of the advanced degrees are in education, the STEM ROCKS initiative is very important since it will engage teachers in STEM ideas and concepts that they would not have been exposed to in their pursuit of advanced degrees in education.

Table VII: Reasons Teachers were Participating in this Activity

Responses	Number of Responses
To renew a current license	1
To obtain an additional license	1
To obtain graduate credit	13
To pursue a personal interest	20
To increase knowledge in content	19
To be considered "Highly Qualified" in the subjects they teach	4
To follow an administrator's suggestion	10

Responses to "Reasons teachers were participating in this activity?" were very positive. The majority of the participants chose to participate in STEM ROCKS to pursue a personal interest and/or increase knowledge of content. The lead teachers were eager and enthusiastic to learn about engineering and introduce it into their science and mathematics classrooms.

Findings of Evaluation Report on Pre- and Post-tests

Eighteen of the twenty-two lead teachers completed the pre-test, an objective multiple-choice test with three parts. The first part measured knowledge of EiE, the second part measured knowledge of Strand A content, the third part measured knowledge of Strand E content. An identical three-part test was made available on-line as a post-test during the rest of July. Unfortunately, it was not clear to the teachers that all of them had been expected to take the first part of the test on EiE content. After completing part 1, each should have only completed the part of the test, either for Strand A or for Strand E, that matched the strand of the Teacher Educator Institute each had attended. The attendant confusion is reflected in the evaluator's observation below that some participants took either a pre-test or a post-test, but not both, and that some of them took pre- and post-tests for both strands. The result was that only eleven teachers (six in Strand A and five in Strand E) out of twenty-two managed to complete the proper pre- and post-testing.

On September 20, 2008, an interim report[7] was received presenting the findings from evaluation research conducted by Davis Square Research Associates on the pre- and post-tests. The central question asked in the interim report was to what extent the teachers were successful in learning the EiE content as measured by the pre- and post-tests.

In the report, the evaluator noted,

> Some participants took a pre-test, but no post-test, and vice versa. Some took the pre- and post tests for both strands. While none of these factors is likely to have much effect on the evaluation of the overall effectiveness of the summer program, they need to be noted herein to better understand what follows in the findings section below.

In a section entitled, Pre-Post Findings, the evaluator presented an analysis of the data taken from the pre- and post-testing and concluded that:

> Table 1 below summarizes the results of the teachers' performance on the tests. There are several items that are worth noting in Table 1. To begin, note the varying numbers of participants who completed the various post-test assessments. The lack of a complete sample here may have influenced the results that are presented in ways that cannot be predicted.
>
> Note that in the "Mean" column the participants show consistent gains. This is highly positive and provides a clear indication that the project has been effective in promoting teacher learning. However, note that the "Approx. Effect Size" column contains only modest values. This means that the magnitude of the change from pre-test to post-test is rather limited. Controlling for pre-tests differences (using a multinominal logistic regression), DSRA found that the gains were spread more or less evenly for both strands and over all participants.

Table 1: Test Scores Summarized

	N	Mean	Approx. Effect Size
EiE Pre	18	6.41	
EiE Post	11	6.91	0.1
Strand A Pre	18	10.33	
Strand A Post	6	17.33	0.1
Strand E Pre	18	16.11	
Strand E Post	5	21.60	0.3

> There are three important considerations that arise from [this data]. The first is that the project was generally successful in reaching all participants who did not have backgrounds in engineering (as so few elementary teachers do). This means that in terms of laying the groundwork for the innovation that the project is seeking to inculcate, the project has made solid progress.
> The second consideration has to do with the unevenness of the testing. This is something to which the project will need to devote greater energy in future iterations. Without the data, or with incomplete data, a complete and minimally inferential picture of project effectiveness will not be forthcoming.
> Finally, the project may wish to re-visit the assessments themselves. The content covered in the tests may well be broader in scope than the project itself, thus creating a situation in which one would be unreasonable to expect to see strong gains from pre- to post-test.

Given the above, DSRA concluded that:

> Teachers made consistent, though not large, gains in their grasp of engineering content. These gains are surely the prelude to successful implementations of engineering units, and thus the project was successful in bringing about the first and most foundational improvement among participants.
>
> In light of the above, DSRA also recommends that the project consider:
> • Revising the assessments to make certain that they are closely reflective (command a reasonable degree of face and content validity) of summer workshop content. The assessments cover a wide range of topics, and it may be that some topics are more germane to actual summer work than other topics.
> • That the collection of the pre- and post-test data be carried out under more formal and structured conditions so as to ensure that all participants complete all they ought to complete.

The evaluator's recommendations about revising the pre- and post-tests and ensuring that all participants submit pre- and post-tests will be reviewed and modifications will be implemented by Spring/Summer of 2009. These changes will be in place in time for the professional development activities for the additional one hundred and eighty-two elementary school teachers.

Feedback from Lead Teachers Participating During Summer of 2008

In October of 2008, eighteen out of the twenty-two lead teachers responded to an on-line feedback survey about the Teacher Educator Institute which they had attended at the Museum of Science. All eighteen described the information presented as "appropriately challenging." All eighteen described the amount of time allotted as "about right."

Twelve respondents described the PD activity as "very relevant" to their job; six described it as "somewhat relevant."

Twelve teachers said they would "definitely" incorporate the material learned into the classroom; three said they were "very likely" to do so; and three said they were "somewhat likely."

Three teachers said they experienced a "large increase" in content knowledge; nine reported a "moderate increase," and five reported a "small increase."

Four teachers described the quality of the instructors as "very good;" seven said "good," and seven said "adequate."

The quality of materials used was rated "very good" by eight teachers; "good" by seven teachers, "adequate" by two; and "poor" by only one teacher.

The information presented was described as "appropriately challenging" for their students by all eighteen teachers.

Four teachers reported that the professional development activity met their expectations "fully"; ten reported that it met their expectations "mostly;" and four reported it met them "somewhat."

Summary of Teacher Perceptions of Engineers and the Teaching of DET

In January, 2009, an on-line survey using the questions developed by Senay Yasar and colleagues at Arizona State University and published in an article in the Journal of Engineering Education was used to assess the teachers' perceptions of engineers and the teachers' familiarity with teaching design, engineering, and technology (DET).

The following summary[8] of the results of that survey was submitted by the independent evaluator on February 1, 2009. (This summary is distinct from the Interim Report quoted above which also contains a Table 1.)

<u>Key Points</u>

- Teachers were enthusiastic about incorporating DET into their teaching
- Teachers saw a lack of knowledge on the part of teachers as the most important impediment to the integration of DET
- Teachers preferred to receive training in a workshop setting
- Teachers expressed highly positive images of engineers and engineering

The following table presents the mean values and standard deviations for each item designed to collect information around teacher attitudes toward DET (design, engineering, and technology). The scale ran from 1 = Strongest disagreement to 6=Strongest agreement. Only those items in italics were found to be significant (Kolmogorov-Smirnov statistic), meaning that there was a greater-than-expected (non-random) consensus around the mean value. For all other items in Table 1 the respondents varied normally. Note that all mean values are positive, indicating a strong commitment to the aims of the project. Note also that the respondents would prefer to receive their professional development through workshops rather than other means.

Table 1: Respondent Attitudes toward DET

Item	Mean	Std. Deviation
I believe DET should be integrated into the K-12 curriculum.	5.29	0.92
Including DET in pre-service education is essential for the preparation of tomorrow's teachers.	5.24	1.09
I would like to be able to teach my students to understand the design process.	5.18	1.19
I would like to be able to teach my students to understand the use and impact of DET (design, engineering, and technology).	5.12	0.93
I would like to be able to teach my students to understand the science underlying DET.	5.12	1.05
I would like to be able to teach my students to understand the types of problems to which DET can be applied.	5.12	1.17
My motivation for teaching science is to promote an enjoyment of learning.	5.12	0.99
In a science curriculum, it is important to include the use of engineering in developing new technologies.	5.12	1.05

I am interested in learning more about DET through workshops.	4.82	1.24
I am interested in learning more about DET through in-services professional development.	4.59	1.33
My motivation for teaching science is to promote an understanding of how DET affects society.	4.53	1.28
My motivation for teaching science is to help students develop an understanding of the technical world.	4.50	1.10
I would like to be able to teach my students to understand the process of communicating technical information.	4.47	0.94
My motivation for teaching science is to prepare young people for the world of work.	4.44	1.15
I am interested in learning more about DET through college courses.	4.12	1.69
I am interested in learning more about DET through peer training.	3.88	1.32
In a science curriculum, it is important to include planning of a project.	3.53	1.33

In Table 2, the respondents used a 1-6 (negative to positive) scale to express judgments around various points regarding values, familiarity, and comfort in dealing with DET. No items were significant, meaning that the teachers varied in a normal fashion. Note the importance of teacher knowledge as a barrier, the low levels of preparation, and the current, rather low levels of DET in teaching. This contrasts sharply with the enthusiasm expressed in Table 1.

Table 2: Teacher Judgments around DET

Item	**Mean**	**Std. Deviation**
How important is lack of teacher knowledge as a barrier to integrating DET?	5.29	0.92
How important is the lack of time in the integration of DET into the curriculum?	5.12	0.96
How important is lack of teacher training as a barrier to integrating DET?	4.53	1.28
How supportive is your school of DET activities?	4.12	1.54
How confident do you feel about integrating more DET into your curriculum?	4.06	1.14
How familiar are you with DET?	3.88	0.86

How important is the lack of administrative support in integrating DET?	3.82	1.38
How frequently do you use DET activities in your teaching?	3.35	1.22
How effective was your pre-service training in your ability to teach DET?	3.31	1.58
How familiar are you with national standards related to DET?	3.19	1.11
How important was DET in your pre-service curriculum?	3.06	1.56

In Table 3, teachers expressed consistently positive attitudes toward engineers and engineering, reprising the positive responses in Table 1. Only the first, italicized item achieved significance (Kolmogorov-Smirnov statistic), and all other items received strongly approbatory responses from participants with the variation in the responses approximating a normal distribution.

Table 3: Teachers' Models in Engineers

Item	**Mean**	**Std. Deviation**
DET has positive consequences for society.	5.76	0.56
A typical engineer does well in science.	4.94	1.03
A typical engineer has good math skills.	4.94	1.03
A typical engineer likes to fix things.	4.88	1.22
A typical engineer earns good money.	4.65	1.06
Most people feel that male students can do well in DET.	4.59	1.54
A typical engineer works well with people.	4.18	1.29
A typical engineer has good verbal skills.	4.12	1.32
Most people feel that minority students can do well in DET.	4.00	1.62
Most people feel that female students can do well in DET.	3.94	1.56
A typical engineer has good writing skills.	3.94	1.20

Conclusions

The professional development activities conducted during the summer of 2008 proved most successful in changing the participants' perceptions of engineering, technology and the engineering design process in a positive and constructive way. The workshop also increased the participants' knowledge of EiE units and how they fit within the elementary school science and math curriculum.

The participating teachers enjoyed mastering the engineering design challenges and worked well together, collaboratively planning lessons and completing the design projects.

The Next Steps

Student outcomes, both content knowledge gained and attitudes toward STEM, are being measured as the units of EiE are implemented in the classrooms of the twenty-two teachers during the spring of 2009. An evaluation of the tabulated results will be available in June, 2009.

In future professional development, engaging teachers directly in engineering design in a workshop setting and using the lead teachers' experiences introducing EiE into their classrooms during the winter of 2008-2009 will be used as a model for introducing EiE to the additional one hundred and eighty-four elementary school teachers and assisting them in integrating it into their classrooms during the remaining two years of the STEM ROCKS grant.

The independent evaluator pointed out flaws in the pre- and post-tests for the teachers and in how the tests were administered. This criticism was constructive and led the principal investigator and the evaluator to review and modify the pre- and post-test questions for the teachers and the process of administrating the tests so as to ensure more complete participation by the teachers during the next two years of STEM ROCKS.

Over the next two years, as the students of the additional one hundred and eighty-four elementary school teachers experience EiE, measures of student outcomes, both the content knowledge gained and student attitudes toward STEM, will be measured.

Appendix[1]

Technology/Engineering, Grades 3–5

Please note: Suggested extensions to learning in technology/engineering for grades 3–5 are listed with the science learning standards. See pages 26–29 (Earth and Space Science), 46–49 (Life Science), and 64–66 (Physical Sciences).

LEARNING STANDARDS

1. Materials and Tools
Central Concept: Appropriate materials, tools, and machines extend our ability to solve problems and invent.

- **1.1 Identify materials used to accomplish a design task based on a specific property, e.g., strength, hardness, and flexibility.**
- **1.2 Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) to construct a given prototype safely.**
- **1.3 Identify and explain the difference between simple and complex machines, e.g., hand can opener that includes multiple gears, wheel, wedge, gear, and lever.**

2. Engineering Design
Central Concept: Engineering design requires creative thinking and strategies to solve practical problems generated by needs and wants.

- **2.1 Identify a problem that reflects the need for shelter, storage, or convenience.**
- **2.2 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.**
- **2.3 Identify relevant design features (e.g., size, shape, weight) for building a prototype of a solution to a given problem.**
- **2.4 Compare natural systems with mechanical systems that are designed to serve similar purposes, e.g., a bird's wings as compared to an airplane's wings.**

Physical Sciences (Chemistry and Physics), Grades 3–5

Learning Standard	Ideas for Developing Investigations and Learning Experiences	Suggested Extensions to Learning in Technology/Engineering (Technology/Engineering standards for grades 3–5 are on page 86.)
Properties of Objects and Materials		
1. Differentiate between properties of objects (e.g., size, shape, weight) and properties of materials (e.g., color, texture, hardness).	Gather a variety of solid objects. Collect data on properties of these objects, such as origin (human-made or natural), weight (heavy, medium, light), length, odor, color, hardness, and flexibility.	*Given a variety of objects made of different materials, ask questions and make predictions about the hardness, flexibility, and strength of each. Test to see if the predictions were correct. (T/E 1.1)*
States of Matter		
2. Compare and contrast solids, liquids, and gases based on the basic properties of each of these states of matter.	Design several stations, each of which demonstrates a state of matter (e.g., water table, balloon and fan table, sand and block table).	*Design one container for each state of matter, taking into account which material properties are important (e.g., size, shape, flexibility). (T/E 1.1, 2.3)*
3. Describe how water can be changed from one state to another by adding or taking away heat.	Do simple investigations to observe evaporation, condensation, freezing, and melting. Confirm that water expands upon freezing.	*Using given insulating materials, try to keep an ice cube from melting. (T/E 1.1)*
Forms of Energy		
4. Identify the basic forms of energy (light, sound, heat, electrical, and magnetic). Recognize that energy is the ability to cause motion or create change.	Play music through a speaker with and without a grill cover. Discuss the differences in sound.	*Design and construct a candle wheel that demonstrates how heat can cause a propeller to spin. (T/E 1.1, 1.2, 2.2, 2.3)*
5. Give examples of how energy can be transferred from one form to another.	Rub two pieces of wood together (mechanical energy) and observe the change in temperature of the wood.	*Design and build a simple roller coaster for a marble or toy car to demonstrate how energy changes from one form to another. (T/E 2.2, 2.3)*

Physical Sciences (Chemistry and Physics), Grades 3–5

LEARNING STANDARD	IDEAS FOR DEVELOPING INVESTIGATIONS AND LEARNING EXPERIENCES	SUGGESTED EXTENSIONS TO LEARNING IN TECHNOLOGY/ENGINEERING (Technology/Engineering standards for grades 3–5 are on page 86.)
	Electrical Energy	
6. Recognize that electricity in circuits requires a complete loop through which an electrical current can pass, and that electricity can produce light, heat, and sound.		• Using graphic symbols, draw and label a simple electric circuit. (T/E 2.2) • Using batteries, bulbs, and wires, build a series circuit. (T/E 1.2, 2.2)
7. Identify and classify objects and materials that conduct electricity and objects and materials that are insulators of electricity.	Provide a collection of materials that are good conductors and good insulators. Have students determine each material's electrical conductivity by testing the material with a simple battery/bulb circuit.	*Select from a variety of materials (e.g., cloth, cardboard, Styrofoam, plastic) to design and construct a simple device (prototype) that could be used as an insulator. Do a simple test of its effectiveness. (T/E 1.1, 1.2, 2.2, 2.3)*
8. Explain how electromagnets can be made, and give examples of how they can be used.		*Make an electromagnet with a six-volt battery, insulated wire, and a large nail. (T/E 1.2, 2.1, 2.2, 2.3)*
	Magnetic Energy	
9. Recognize that magnets have poles that repel and attract each other.	Balance ring magnets on a pencil. Note: The shape of a ring magnet obscures the locations of its poles.	*Design and build a magnetic device to sort steel from aluminum materials for recycling. (T/E 1.1)*
10. Identify and classify objects and materials that a magnet will attract and objects and materials that a magnet will not attract.	Test a variety of materials with assorted magnets. Include samples of pure iron, magnetic steel, and non-magnetic metals in the materials tested. Mention the two other magnetic metals: pure cobalt and pure nickel.	

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