Evaluation of the Museum of Science PCET Project

Evaluation Report

Submitted by Russell Faux, Ed.D.
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Executive Summary

The current report presents the data and findings from a survey conducted by the Boston Museum of Science and Davis Square Research Associates (DSRA) as a part of the external evaluation of the Museum's Pre-College Engineering for Teachers (PCET) project, funded by the National Science Foundation. The survey was administered to the teachers (N=120) who participated in PCET project. The overall goal of the PCET project is to assist elementary and middle school teachers to incorporate engineering in their classroom practices.

The key findings from the survey include:

- Participants grew significantly in their knowledge of engineering and their confidence in teaching engineering
- Participants anticipate the PCET experience will exercise a strongly positive and enduring influence on the future teaching.

Sample & Method

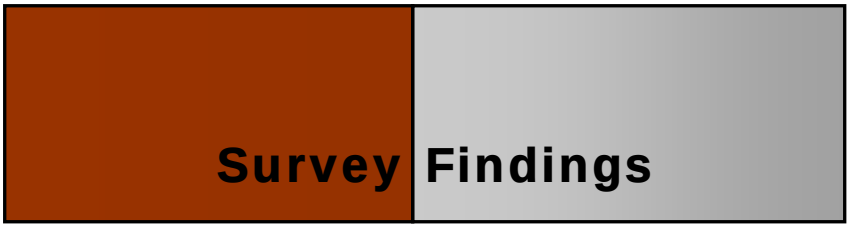
The sample for the survey included all participating teachers (N=120 of 157, a response rate of 77%). A more complete description of the participants will be made available in the Project report. The survey was developed in collaboration with the project leadership and employed mainly Likert scale-type questions, with many opportunities for open-ended responses. The survey was administered online, with the data downloaded by DSRA for cleaning, analysis and interpretation. Some questions were primarily formative or administrative in content, and no analysis of the data derived from these questions is included in this report.

The statistics used frequently relied on the Kolmogorov-Smirnov and paired samples t-tests. The former test reveals the extent to which responses to

individual items varied among the total pool of respondents. The latter compares the responses of a Time 1 (prior to participation, judged retrospectively) to Time 2 (end of the summer program). The effect sizes presented below are rough estimates using averaged responses and calculated with the eta squared statistic. The qualitative data from the open-ended responses were analyzed using HyperResearch.

The key questions for the study included:

- What are the benefits that the teachers attribute to their participation?
- What effects do the participants attribute to the program with regard to their intentions to continue to teach engineering and their confidence in being successful at infusing their teaching with engineering?



In this section of the report DSRA presents the findings from the online PCET survey. The first section will look at teachers, the second will look at students, and the last section will examine the prospects for the longevity of the outcomes.

Participant-Level Effects

In Table 1 below DSRA presents the self-reported changes among the responding teachers. Note that for all items the respondents reported having made significant gains (using a 1-6 Likert scale), a powerful indication of Project success. The effect sizes vary, from the small effect of the final item, to the very large magnitudes seen in the first five items. What one would normally expect to see is larger effect sizes associated with those items most closely tied to the innovative content of the project, and in fact, this is exactly what DSRA found in the case of the PCET teachers. The lower effect sizes tend to be attached to project impacts, in other words, in areas that are not central to the Project outcomes, but are rather secondary effects.

Table 1: Participant Self-Reported Change

Item	Before PCET	Since PCET	Effect Size
I understand the range of engineering disciplines.	2.41	5.16*	0.83
I understand what engineers do.	2.96	5.31*	0.79
I understand the engineering design process.	2.33	5.41*	0.81
I incorporate engineering concepts into my teaching.	2.08	4.43*	0.72
I am confident teaching engineering and technology concepts.	2.28	4.60*	0.74
I am confident teaching science concepts.	4.27	5.08*	0.39
I am enthusiastic about teaching engineering concepts.	2.71	5.31*	0.72
I am committed to engineering teaching and learning.	2.50	5.03*	0.72
I am fearful of teaching engineering concepts.	3.21	1.93*	0.27
I am confident guiding my students in an engineering design challenge.	2.38	5.01*	0.78
I am confident teaching problems that don't have one right answer.	4.16	5.22*	0.44
I am confident facilitating a classroom driven by student inquiry.	4.26	5.11*	0.42
I lead hands-on activities that promote learning by doing.	4.54	5.22*	0.36
I encourage my students to learn from their mistakes.	5.23	5.55*	0.11

*Significant at $p<.001$ (paired samples t-test)

When asked about various aspects of their teaching practices, one would expect to see somewhat lower numbers than seen in Table 1. This is because, in most cases of professional development projects, teacher learning precedes teacher practice. In the case of the PCET respondents, this pattern holds true. Again using a six-point Likert scale, respondents reported having made significant progress across all domains targeted by the Project, with just one exception (the use of calculators/computers). The exception of the calculators/computers is to be expected, as increasing the uses of these technologies was *not* an objective of PCET. The small change measured here provides some indication of the validity of the other items, as it provides a kind of "boundary" to the scope of the treatment. Overall, the effect sizes seen here are more moderate, with normal variations in the extent to which the respondents' participation was the source of

the changes. Even for the last two items, the respondents answered with a normal variation (though with a highly elevated mean), a somewhat surprising finding given the innovative qualities of the PCET undertaking.

Table 2: Participant Self-Reported Change

Item	Before PCET	Since PCET	Effect Size	Extent change is due to PCET
Students work collaboratively.	4.16	4.68*	0.32	4.20**
Students manipulate data.	3.49	4.16*	0.40	4.33
Students undertake open-ended projects.	3.50	4.22*	0.31	4.60
Students collaboratively discuss how to solve problems.	3.68	4.51*	0.40	4.54
Students explain their problem-solving strategies.	3.88	4.54*	0.33	4.60
Students explore problems related to everyday life.	3.29	4.28*	0.47	4.54**
Students use calculators/computers.	3.71	3.77	0.01	3.71
Students learn about engineering examples.	2.08	4.41*	0.67	5.44
Students use an engineering design process.	1.90	4.30*	0.64	5.52

*Significant at $p<.001$ (paired samples t-test)
**Significant at $p<.05$ (Kolmogorov-Smirnov statistic)

In terms of the effects of participation on the respondents' teaching in other areas, the teachers answered with a significant (meaning, with a greater-than-expected consensus) that participation had a moderate effect on their teaching other content.

Table 3: Additional Effects on Other Subject Matter Areas

Please indicate the extent to which your participation in PCET has had an effect on your teaching in these subjects:	**M**
Math	3.57*
Literacy/Language Arts	3.34*
Social Studies	3.15*

*Significant at $p<.05$ (Kolmogorov-Smirnov statistic)

When asked to elaborate on what the changes were, respondents tended to cite an increased use of inquiry, or uses of the engineering design process applied to areas not normally characterized as unique to engineering. The agent for these changes was alternately the teacher and the students. The following is a sampling of their responses:

Table 4: Open-Ended Responses Regarding Classroom Changes

Changes in Practices	Changes Among Students
• I do more open ended inquiry-based lessons. Exploring concepts rather than one answer. • I would ask more open-ended questions of the students as well as ask them how else they might find a solution. • The literacy part came from in using the story connection and transferring that to a few of their reading stories; example, what problem is showing up at this time in the story and what steps might the characters do in order to solve it. With the social studies in studying the regions of the US, it was easier to help the students see why people settled where they did and the expansion of the country. It was also good for the students when we were discussing the use of machines during the immigration unit. • It gave me more background knowledge to help my students facilitate their open discussions in more than the areas I was comfortable teaching them in.	• Students gained skill in their ability to articulate the process they used in designing their solutions to problems • When there is a new concept in math the students look at the way they can incorporate the design process into finding the solution. They now realize better that there may be several paths that they could follow in order to reach the solution. The literacy part came from in using the story connection and transferring that to a few of their reading stories; example, what problem is showing up at this time in the story and what steps might the characters do in order to solve it. With the social studies in studying the regions of the US, it was easier to help the students see why people settled where they did and the expansion of the country. It was also good for the students when we were discussing the use of machines during the immigration unit. • Students gained skill in their ability to articulate the process they used in designing their solutions to problems • When there is a new concept in math the students look at the way they can incorporate the design process into finding the solution. They now realize better that there may be several paths that they could follow in order to reach the solution.

Student-Level Effects

Survey respondents were asked a series of questions about the student-level benefits of using the EiE materials and associated resources. In Table 4 below the teachers' responses are summarized. Note the consistently high judgments of the teachers, with a great deal of unanimity for each of the items. Investigating further DSRA found no significant differences among the various student groupings, a clear indication that the teachers found that EiE worked well with diverse populations, whether low- or high-achieving.

Table 5: Teacher Reports of Student Benefits

Please indicate how strongly you agree. EiE works well for my students	**M**
with cognitive challenges	4.78*
with linguistic challenges	4.50*
with behavioral challenges	4.48*
who are gifted and talented	5.39*
who are girls	5.08*
who are children of color	5.40*
who are at-risk in other ways	4.78*

*Significant at $p<.001$ (Kolmogorov-Smirnov statistic)
Scale: 1=Strongly disagree; 6=Strongly agree

Teachers were asked to expand upon their answers to the previous items. Students were said to benefit in a variety of ways, cognitive, behavioral, and social. The materials were judged engaging and students, occasionally with additional support, were able to benefit from their uses. The following is a sampling of what the teachers wrote:

- In blended groups, the children put those challenging bridges together. They also had to build a bridge out of materials from home and bring that in. So, while EiE was introduced, the class explored other areas of bridges and scientific inquiry. The students did enjoy the hands on experiences, versus just working through a book, and some of the girls were extremely good at reading and putting the bridges together.
- My class was an inclusion class this past year. The students on IEPs, with a few modifications, were able to access these lessons for the most part. They did need some support that wasn't offered in the unit but that was possible with my knowledge of the child's specific needs.
- Children who are not always the most successful academically have a real opportunity to shine here. Also, teamwork is emphasized and valued.

- Your program works for most students because of the hands on component. They are involved so there less time for them to be off task. it is a great time to allow the brighter students to lead and for the more challenging student to fully participate.
- The students just ate up Catching the Wind. The hands-on experience was so engaging for the kids! They also enjoyed the story component of Leif and his adventures. They learned a lot about Denmark, too.
- Kids who are behaviorally challenged are highly engaged, and so usually stay on task w/ hands-on work. They are less successful w/ paper designs (planning) and recording results. Kids w/ cognitive delays struggle w/ challenging vocabulary and sophisticated concepts.
- The unit Designing Walls was a huge success across the board. It provided the brighter students to do individual investigations and have extensions to the activities. My behavior students were entirely connected to what was going on. I saw no difference in the engagement and success of students according to gender.
- This program works well for students with linguistic challenges b/c it is so hands-on and visual. I had a behaviorally challenged student this year who had trouble with EiE because his main area of disability is related to working with others. This program is amazing for 4th grade girls! I think it really gets them thinking that engineering could be an option for their future.

When asked to compare EiE with traditional science content, the responses of the participants were overwhelmingly positive and nearly unanimous.

Table 6: Student Benefits Relative to Traditional Content

Based on your experience teaching EiE (in comparison to teaching traditional elementary science curricula) please rate the degree to which you agree with the following statements:	**M**
Students learn science concepts better	4.69*
Students are more engaged	5.14*
Students are more collaborative	4.73*
Students are more creative	4.85*
Students make more real world science/engineering connections	5.29*

*Significant at $p<.001$ (Kolmogorov-Smirnov statistic)
Scale: 1=Strongly disagree; 6=Strongly agree

It is well-known that teachers are under considerable pressure to meet local learning standards. Recalling the innovative qualities of the EiE content and materials, it is reasonable to assume that the teachers needed to find ways of incorporating the new engineering content without driving out prescribed content.

Consequently, teachers were asked about how they balanced the two, what sorts of adjustments they needed to make, in order to harmonize the demands of the curriculum and those of EiE. In general, teachers spoke of the usefulness of EiE in expanding student understanding of required conceptual learning, further strengthened through the heightened levels of engagement teachers found when using EiE. The following is a sampling of what the teachers wrote:

Table 6: Additional Benefits to Students and Practice

Student-Level Benefits	Classroom Practice Benefits
• I think the EIE curricula help students to place a higher value on the content portion of the curriculum. For example I think that students will remember the parts of a flower as a result of making the hand pollinators. I think the class who took their prototypes outside to use them will have the best long-term retention of the flower parts. • What was introduced to my students in a more formal way was the engineering aspect of seeing a problem that needs a solution. The students really responded to that. • In just takes the science and learning to whole new level. They explore, experiment, collaborate, and have the freedom to challenge themselves and take the learning wherever their minds can take it. A great experience! • The students were able to understand technology and apply it to creating hand pollinators. Traditionally the students grow plants and pollinate the plants with a dead bee. However, the EiE kit helped the students understand pollination through creating their own pollinators and learned the facts of how important pollination is to plants. • It allows the students to be independent in their investigation learning. Also, they become more engaged with hands on activities and allows them to ask questions and develop critical thinking skills.	• These lessons allowed me to have more hands - on activities than in the past • I felt that this unit was a great follow up to the science unit I taught first. After the students had had some exposure to the concepts/meanings of pitch, volume, frequency, tension, etc., they were ready to apply their learning to the EiE process. I also liked the connection and extension EiE made to real world problems of acoustical engineers. • As Enrichment Specialist, I don't use one science curriculum to teach science in the classrooms. My science lessons are almost always hands-on, so I appreciate the EiE lessons. I have included engineering design challenges in past years. • After teaching the water cycle and discussing it, we moved right into discussions of how we get our drinking water and why towns and cities send out reports indicating what's in our drinking supply. We discussed reservoirs and how some local towns have had problems with their drinking water. We talked about the types of impurities that can be present in water and this led nicely into the EIE story and lesson plans that I used for this unit. • We were able to relate the Designing water filter unit to real world problems in Burma and China-bringing in SS and Science

Prospects for Institutionalization

Beyond the very strong outcomes seen in the data above, the prospects for the sustained uses of the EiE materials were an added area for DSRA evaluation research. To begin this investigation the survey asked a series of questions about interest and support from essential constituencies. The finding of significance in five of the six items in Table 6 below indicates that the experiences of the participants resemble one another to a greater-than-expected degree. In other words, the pattern of moderately supportive environments appears to be widespread across many circumstances. The mean values seen in the Table are relatively high, especially in view of the innovative qualities of EiE.

Table 7: Prospects for Sustainability

Please describe the level of interest you observe and the level of support you receive when teaching EiE, from:	**M: Interest You Observe**	**M: Support You Receive**
Your administration	3.73*	3.32*
Your colleagues	3.89*	3.49
Your students' parents	4.27*	3.95*

*Significant at $p<.001$ (Kolmogorov-Smirnov statistic)
Scale: 1=No interest/support; 6=Great interest/support

One way in which sustainability is achieved is through an extended weaving of EiE in a variety of content spaces. In this case, most of the content connections were made in subject matters that are generally considered close to engineering, with other areas, such as art, receiving much less in the way of connections to EiE. Note that none of the values in Table 7 below are significant, meaning that the teachers varied more or less normally, in their responses to the items.

Table 8: Content Connections

We asked you to write content connections for EiE. Please indicate the extent to which you have made additional formal and/or informal content connections in the following subjects:	**M**
Science	4.33
Real World/Immediate Environment	3.84
Math	2.93
Current Events	2.80
Literacy/Language Arts	2.75
Social Studies	2.21
Art	2.19

Scale: 1=No connections; 6=Significant connections

In all events the teachers themselves expressed a strong and united intention to continue using the EiE materials in the future. With a significant mean value of 5.40 (on a 6-point Likert scale), teachers appear to be of nearly one mind in their firm plans to continue using EiE. When asked to explain their intentions, the teachers spoke of a variety of circumstances, ranging from their personal commitment, to the pressures of time and money, and to the relative degrees of administrative support. The following is a sampling of what they wrote when they were asked to expand upon their intentions to continue to use EiE:

Table 9: Comments on Sustainability of EiE

Commitment	Challenges
• My district has purchased some sound units to use. • I plan to definitely do both the building bridges unit and the membrane unit. • I will be moving to a new grade level next year, so I will be using a different set of materials, but the benefit that the students receive is well worth the sharing of materials with another teacher. The problem-solving is something that carries over in all content areas. • I believe in this type of teaching very much. The EiE materials allow me to bring this type of teaching and learning in to my classroom. • I loved teaching these units and will continue to do so.	• I will do some of the lessons, but will not be able to do the total unit due to lack of class time and prep time • I may not be as well equipped as the kits you sent me, but i should be able to pull materials together for more engineering challenges. • I just need the funding. Our school is strapped for money and we have a new principal this year. I am not sure at this time how funds will be distributed. • I have not discussed with my administration whether or not I can reorder materials. I would like to teach the unit again next year but am not sure... • My students and I enjoyed the Wind unit very much, but it is very time consuming. It was difficult for me to complete all the other curriculum I was required to teach. I want to teach the unit again, but I will have to be careful with my time.

Final Reflections

In concluding the survey teachers were asked to reflect more generally on their experience in PCET. The most recurring themes regarding personal and professional change had to do with increases in confidence around teaching engineering to children, expanded knowledge, leaps in enthusiasm for engineering and even teaching in general, and a strong commitment to continue (as seen in the preceding section). DSRA broke down the comments into three broad domains in Table 8 below, but the reader should note that these domains are not at all equally represented. They are presented here as a means of portraying the range of value that participants attributed to their involvement in PCET.

Table 10: Examples of Teacher Change

Teacher Change	Change in Practices	Student Responses
My greatest personal and professional change was getting over the hurdle that engineering was only for those who attended engineering schools and learning that there were so many areas where engineers are needed and can and do provide a contribution to society. The course helped me get excited about teaching science again. I felt I was in a slump of repetitive teaching. The program helped bring new perspectives and challenges for me and the students. I have more confidence in my ability to set up ahead of time experiments and activities that are complex hands-on learning experiences. I now see engineering in everything I touch and think more about it.	I plan to at least try to incorporate engineering/technology in every Science unit I teach in the future. The greatest change is the amount of focus that I put into making real life connections to the science that is being taught. I also try to incorporate engineering applications whenever I can. I think that the engineering design process becomes a part of the children's and my daily repertoire. I was able to bring technology and engineering into our everyday science discussions and make real world connections- ESPECIALLY for the girls in my grade 3 class!	Using the engineering design process has helped students to work through a systematic method of finding solutions to problems. Allowing students to apply opportunities to expand their own learning through hands on activities. I think most importantly, I have students try to solve problems on their own and have them learn from mistakes. This was important for me to learn because students benefited from having to come up with a solution.

Teachers were asked about how they reconciled EiE with the demands made upon them due to the high-stakes testing from NCLB (*In this climate of increased accountability, growing time constraints, etc. why have you chosen to devote time to the EiE curriculum?*). The responses varied widely, with some continuing to cite the behavioral and affective responses of the students, the opportunities for personal and professional growth, while yet others saw engineering as a deeply purposeful endeavor, one that is necessary for the future of our civilization. The following is a sampling of the teachers' responses that focused on the broader purposes of using EiE (with the other themes adequately developed elsewhere in the current report):

- Because it is grounded in a philosophy that I believe is crucial to teaching and learning. I believe it is my job to find avenues to teach in this way that

fit within the standards that we teach by. EiE is one effective way to do this.

- I believe engineering is what we will need to address the mess we have made of this earth.
- I believe the future of science lies in engineering and I think we as educators have to be ready to incorporate this into our teaching - this is where the future lies.
- I think it's a great experience for children and opens doors to careers and ways of thinking they may not be aware of. It's difficult though because my school dictates what we teach, when we teach it, and much of how we teach it. It can be difficult to try to go against the grain-even if it's a beneficial program like EiE.
- I think we have a crisis in this country in that we are not training enough students to go into the fields of math, science and engineering. If we can show them that these fields are fun when they are very young, we may change their future paths.
- I think science is very important for the future of our children and country and want to inspire young people to become more interest in science.
- The children learn so much more and are thoroughly engaged. We should do more of this type of work and less of some others!
- I feel it is important, especially for girls, to become invested in science and math. I feel the payoff in teaching advanced science and math skills young is developing that love of learning early. Engineering is a high paced and quick developing career that needs great thinkers and a lot of them!

On the penultimate question teachers were asked for ways to improve the project. The responses to the question can be summed up in the word "more." Teachers want more training, more resources, more opportunities to expend their EiE social network. The following is a sampling of the teachers' responses:

- Perhaps it would be helpful to have a follow up course, or some kind of conversation between teachers using it to help think of other ways to implement the curriculum.
- upkeep...I think it would be useful for teachers to get together to share the projects, activities, and lessons that they have created/added with each other.
- shorter lessons, activities that require less materials and prep, much shorter story to accompany the lesson
- I would like to try other EiE units more closely related to my curricular topics. The materials, as I have stated, are easy enough to obtain.
- What I thought was lacking, was the fact that we did not have books for the literacy piece. It is difficult to have kids sit through your reading of the story, and also to see illustrated examples of what the finished product should closely resemble.
- Replenishing materials that can be easily ordered and affordable.

- I would love to see my school system work with all teachers to introduce them to these types of materials.
- I'd love to have more teachers at my school become familiar with it, so there would be a support network and someone to discuss the unit as we went through it.
- I would like my school to provide the consumable materials.
- I would like to see the storybooks rewritten. They are much too long and complex for young children. They took way too much time.
- Cooperating/ Mentor teachers or engineers to help new PCET trainees with the implementation.

On a final open-ended question (*Is there anything else you'd like to share with us?*), teachers expressed their gratitude for the qualities of the materials, training, and even the transformative value of participation. The following is a sampling of their responses:

Table 11: Additional Open-Ended Participant Comments

Appreciation for Experience	**Quality of Materials**
• Thank you for a wonderful experience. Keep up the wonderful work you are doing. • It is a great curriculum. I appreciated the opportunity to participate and share what I learned with my students. I feel that the more I teach the units, the more I will learn and refine my teaching. • Thanks for an amazing experience. • I think EiE is a wonderful program. When I teach it, I can't help but think how amazing it would have been to have these same experiences as a child! Well done! • Thank you for your dedication to Science. • I am proud I was chosen to participate in such a well-run program. • I am extremely proud of [my students] and I have to say proud of myself for succeeding in an area where last summer I felt very inadequate. • Thank you for the great experience!! It was well worth it. • This has been an amazing process for me.	• I was blown away by the quality of the program offered to me and then the units. I told myself not to get too over the top with it because the students might not find the excitement and value that I did. They did! It was incredible to see the energy and focus from my group. Their walls were on display and will be . . . for all the parents to view. • You are doing a great job! Workshops are excellent. The activities and kits are great to and age appropriate. • Your programs are top notch! Keep up the excellent work! • I really have learned so much working with MOS and love the materials • *Nature* aired a program in the fall on Disappearing Bees, which had a short 10-minute film clip of people in China hand pollinating pears. It was a powerful example to use with kids • The kits are great!

Conclusions & Recommendations

The above data and analyses combine to create an image of a program that has had far-flung ambitions and has gone remarkably close to their full realization. The participating teachers were strongly united in their appreciation for the many values of participation, with increases in learning, confidence, and commitment to teaching engineering recurring throughout their responses. There were considerable references to the positive responses of students, and to the long-term benefits of the inclusion of EiE in the curriculum.

The data on the sustainability of the project offer a more tempered view. It is less certain if the teachers will be able to find the resources needed to continue to teach the units, if the engineering design process will find broader acceptance in other content areas, and if more teachers adopt or adapt the EiE content or approach in their own teaching. Literature on professional development frequently cites the need for a strongly proactive local leadership, high-functioning social networks, and a supportive policy (especially curriculum and assessment) environment. These components appear to vary across the many venues of the participants, and thus it is reasonable to assume that in some areas EiE will command a greater sustainability and dissemination than in others.

Of course, given the generally-accepted hazards of predicting the future, one cannot with confidence write of long-term, enduring effects. Whether the program turns out to be a powerful experience, but one that exercises little in the way of lasting and widening change is an open, empirical question that the project would do well to explore.

Given the above, DSRA suggests the following:

- That the Project devise ways to continue to gather data from the participants with an eye toward assessing the extent to which the present outcomes endure
- That the Project look for ways to use current participants in other, related roles, harnessing some of their energies to reach other teachers and widen the scope of Project beneficiaries.

Evaluation of the Museum of Science PCET Program

Interim Report: Draft

Submitted by Russell Faux, Ed.D.
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Executive Summary

The following report presents the findings from the evaluation research conducted by Davis Square Research Associates (DSRA) for the Boston Museum of Science PCET (Pre-College Engineering for Teachers) project, with a focus on the series of summer workshops conducted at three sites (Tufts University, UMass-Lowell, and Worcester Polytechnic Institute) during the summer of 2007. This part of the NSF—funded project seeks to improve the participants' understanding of engineering and their capacity to teach engineering concepts and methods in elementary school classrooms.

Key findings include:

1. Participants improved in their knowledge of, and attitudes toward, engineering for teaching
2. Participants judged the Engineering is Elementary (EiE) materials to be of high value and likely to be very well received by students
3. Participants gained in their confidence in teaching engineering
4. Participants expressed considerable eagerness to begin the implementation of engineering units

Sample & Method

The sampling frame for the report is coextensive with the participants in the summer program (N=162). Further information on the participants and activities will be found in the project report.

The evaluation method relies upon one online survey and three focus groups, developed by DSRA in collaboration with the PCET project management team. Rather distinct from previous surveys, the current survey relied somewhat more heavily on qualitative data gathered through open-ended questions. These data were gathered online, then downloaded by DSRA for analysis in SPSS.

All focus groups were conducted at the Tufts site. These data were transcribed and then analyzed by DSRA using HyperResearch.

The key questions for the survey were:

- What were the effects of participation in PCET on participants' knowledge, attitude, and instructional practices around engineering content?
- What are the responses to the participants to the EiE material?
- What are the prospects for implementation of the engineering units?
- What other effects of participation can be attributed to PCET?

Survey Findings

In this section DSRA presents the findings from the survey. The first section presents the data from all respondents, from all workshop sites, in aggregate form.

When asked for a general response to what worked well in the workshop, participants quickly established a pattern that would hold true throughout the survey. This pattern can be characterized as tremendously positive, with the areas of appreciation roughly divisible into three areas. These areas are (1) more or less specific learning gained through interactions with other teachers, presentations, and the EiE materials, (2) an appreciation for the workings of the professional development activities, and (3) reported changes in awareness, attitudes, and behavior. For the first responses to the opening question, DSRA has taken created three categories of utterances. It should be noted that these categories are not so much watertight conceptual acts, as they are a way of making sense of the general trendlines in the responses.

Table 1: Sample of Participant Reactions to the Workshops

Interactions	Activities	Learning
• Interaction with other teachers; having the units presented by teachers who had already taught them. • I enjoyed the interaction of the teachers and logical and creative thinking skill that were used when working with the hands-on projects. • Working in groups trying the lessons/activities (i.e. building bridges, windmills and water filters). • I enjoyed being in the company of same grade teachers so that ideas that were shared were things that we could actually use. • Understand the challenges. • Working on the projects in teams, looking at the binder materials, listening to the staff who have done the units, having an engineer available to answer questions and give suggestions • I meet many teachers who shared many great ideas. I received a lot of background information to assist me when I teach these units.	• All of the "hands on" activities • I liked that we got to try out the different activities. • It was great to be able to experience the hands on activities for many of the lessons as this really helps to think through the way it will work with students. • This was one of the best workshops I've ever attended. It was a great mix of listening and doing. The opportunities to go through the binders and work out each lesson were invaluable. Teachers never have that kind of time to experience it themselves! • I liked the flow of the workshops. Lecture, or listening activities were mixed with hands-on lessons that broke up the day and kept it interesting and fast-moving. • The hands on activities and the freedom to make mistakes refine and retest • Doing the various activities, gave me confidence to try them in my own classroom. Having several of them showcased gave me a good indication of what they were about.	• The explanations of units. The trial and error on our parts to see how they could fit into our curriculum and grade level. The consistency of the scientific method stages/stages of inquiry and how it ties to D.O.E. standards/learning strands. Having the "theory" of the units taught by engineering expertise, as opposed to this is how to do the unit with no theory foundation, which was my whole purpose in taking the course. • I left the training with a new respect for the field of engineering. • I enjoyed learning about engineering and discovering that it's not some scary, difficult subject, only for the elite. • It was great to have a college engineering professor lead the program; loved touring the plastics labs; loved trying out the units; loved learning background information about U Mass Lowell North campus; loved the ground water experiment at the Boot Mill and the tour of the water turbine. It was a very worthwhile week.

When asked for the judgments on the EiE materials, participants were overwhelmingly positive in their responses. In Table 2 below, note not only the very high mean values, but also the very low standard deviations (SD), indicating a significantly (Kolmogorov-Smirnov) higher than expected level of consensus among the participants. This is a remarkably strong finding, especially in the light of the highly diverse group of teachers responding to the questions.

Table 2: Participant Assessments of EiE Units

Using the scale, please let us know whether you agree or disagree with the following statements about the EiE curriculum.	**M**	**SD**
EiE units are well designed.	6.59*	.802
EiE units fit into my required curriculum, rather than being "one more thing" to teach.	6.31*	.962
EiE units are well matched to my level of students.	6.13*	1.215

*Significant @ $p<.05$ (K-S)
Scale: 1=Greatest disagreement; 7=Greatest agreement

When asked to expand on their responses to the questions on the quality of the EiE units, teachers declared that the materials are an excellent fit for elementary school students and teachers. The qualities more often cited are the hands-on approach used by the units, the strongly sound pedagogical design of the units, the ease with which they can be adapted to fit local circumstances, the collaborative nature of the activities, and the many ways in which using the units promotes a greater awareness of the ubiquity of engineering in the lives of the students.

Of some concern for respondents was the length of time required to do the lessons, the acquisition and management of material resources to support the lessons, and the reading level of the EiE stories.

Table 3 below offers a sampling of participant responses to a question on the strengths and weaknesses of the EiE units.

Table 3: Sampling of Participant Comments on EiE Units

Good Match	Challenges to Match
• The EiE units are interesting and engaging learning experiences. I feel that the concepts are appropriate for my age group. The engineering concepts feed on the natural curiosity of my young "engineers." I also like the clear-cut design and scaffolding of the units. • I thought most of the units were developmentally appropriate. The literature may be a little lengthy and I may need to play around with the management piece, but overall I see the units as highly motivating for students. • There are a lot of strengths. Using a story to introduce the unit and the big activity at the end are two important parts. Adding a parent component may help justify the time spent on the units. • I could easily integrate the design process into many aspects of my classroom. I liked the way you do some mini experiments before designing the challenge project. I also like the way the challenges depend on cooperative groups which reinforces the importance of group work to get things done. • The bridge building unit will fit in with my curriculum very easily. I already do bridge building with my students during the first chapter of the science book. I will expand on this activity using EiE using the bridge building unit. The strengths of the units are the hands on activities. These activities are directed at all learners and will come in handy in my diverse classroom. • I think the units are well designed. I'm looking forward to trying them out in my classroom. As you know, finding the time is always a struggle. This type of hands-on curriculum is very developmentally appropriate for most first graders.	• I think that the literature connection provided for each unit is valuable but would love to see more grade appropriate picture book-style books in the future. Attention can be a problem at that age. • I can work a unit into my overfilled curriculum, but there are a lot of activities, set up and take down time, and materials to store in my overstuffed classroom. Just having the knowledge from this course will help me present things differently to the students, and help them to get a little more into engineering. • It is a challenge to fit them in an already "packed" curriculum, but the activities are so well-planned according to ability level, group size, etc., that I think they should be successful! It is such a dilemma. We have to cover so much curriculum in a short span of time. On the other hand, children learn and remember the material better when they are engaged in activities rather than just taking notes, completing worksheets and reviews, and taking assessments. • Some of the projects (bridges for example) seem too involved and lengthy to realistically fit into our already jam packed curriculum. However, I think they would make for great after-school or summer enrichment programs! • They are a bit lengthy. They require prior knowledge, so on top of teaching the lesson, you have to add 2 other weeks to do the EiE unit. Elementary teachers are very pressed for time. However, I do think that it is a wonderful program. I think it is very important that kids learn engineering. It helps them in all areas of school. It also allows them to think outside the box, which they need to learn how to do.

Participants were asked a series of questions on how well the workshops met their goals. In Table 4 below, DSRA presents these data. Note again the very high mean values, the very low standard deviations, and the consistent finding of statistical significance (K-S statistic). It is difficult to envision of series of workshops achieving a greater level of success across such widely varying groups.

Table 4: Participant Judgments of Workshop Success

Using the following scale, how well did the PCET workshop meet the following goals?	**M**	**SD**
The EiE units and materials were presented in a manner so I feel comfortable using them in my classroom.	6.61*	.653
The workshop provided strategies for doing engineering in my classroom (assessment, classroom management).	6.40*	.817
The workshop prepared me so I feel ready to do an engineering design project in my classroom next year.	6.68*	.585
The workshop allowed me to learn by doing.	6.89*	.371
The workshop gave me sufficient introduction to the MA Technology/ Engineering State Frameworks.	5.87*	1.182
The workshop had a good balance of speakers, long projects, shorter activities, and discussions.	6.37*	1.089
The workshop was well planned.	6.18*	1.298

*Significant @ $p<.05$ (K-S)
Scale: 1=Greatest disagreement; 7=Greatest agreement

Of particular interest to the evaluation research was any gain in knowledge among the participants. Given that the administration of pre-post testing was not feasible, DSRA relied on self-report (Table 5 below). These data are once again very strong, with low mean values and consistent levels of statistical significance (K-S).

Table 5: Participant Reported Gains in Knowledge

How much has your knowledge and understanding of the following improved as a result of PCET?	**M**	**SD**
My knowledge of the range of engineering disciplines	3.69*	.573
My knowledge of what engineers do	3.68*	.627
My knowledge of the pervasiveness of engineering in our society	3.64*	.665
Understanding that there is not necessarily one "right" answer for engineering problems	3.47*	.850
My knowledge of the MA technology/engineering frameworks	2.75*	.827
My knowledge of the engineering design process	3.59*	.636
My knowledge of the types of constraints that influence the design and selection of engineering criteria	3.30*	.771
My ability to analyze engineering solutions that my students may come up with	3.17*	.719

Significant at $p<.05$ (K-S)
Scale: 1=Not at all; 2=Slightly; 3=Moderately; 4=Greatly

Teachers were asked how their awareness of engineering had changed through participation. The responses were very positive once again, with only a handful of respondents reporting no change. The reported changes were divided, again very roughly, into two categories. The first category captured responses that referred to general changes in awareness. These responses tended to speak of a widening of the respondent's consciousness of the work of engineers in the world. The second category was reserved for responses that made reference to a change in attitude toward engineering, or some change in behavior readily associable with participation in the project. Table 6 below presents a sampling of responses for these two categories.

Table 6: Sampling of Participant Responses

Awareness	Attitude & Behavior
• It has enhanced my understanding of engineering and technology by exposing me to many real life situations where engineering is employed. • I am more conscious of how and where engineers have made their mark and that the range of designs and solutions is immeasurable. • This workshop has made me more aware of the improvements that engineers have made and could make in our world. As a result of this workshop I not only gained a greater understanding of engineering and the design process but now I also have a new appreciation for recycling plastics! • I hadn't realized how engineers influence so many different aspects of our everyday lives. It will be interesting to present this information to my students and to let them know what kinds of opportunities are out there for them in the world of engineering and technology. • It has broadened my perspective on engineering and the importance of introducing it to children in the classroom. • I had a very narrow view of what engineering and technology was. but PCET has "opened my eyes." • My dad was an engineer (Mechanical/Project). I feel that after this workshop I more deeply appreciate the work he did.	• I have become a bridge fanatic! I was able to go home and explain my projects to my 4-year-old son, who was fascinated. • I was quite ignorant before the workshop. I am observing technology and design all around me know. I feel excited to bring this knowledge to the classroom. • I really step back and look at things more closely and see how it relates to what we learned at the workshop. I found I talked to my family about this quite often when the workshop was finished. • I never looked at the world as full of engineering projects. Since the class I have seen the world differently...seeing engineering projects everywhere. • I am better able to explain (or attempt to) even complex engineering and technological concepts. • I will analyze different types of objects that I am surround by in my everyday life. • It certainly has. I often wonder how a bag of coffee beans ended up on the shelf at the supermarket, how a bridge was built in the water, etc. This course made me realize how much thought and often collaboration goes into designing and creating things. I think the workshop makes one wonder more and ask more questions. • Yes, I never stopped to think how almost everything (except nature) around us has been influence or touched in someway by the engineering process. It also made me excited to introduce engineering as a career path to all students but specifically girls.

When asked how participation in PCET has changed the way they teach, participants made reference to both specific and generalized effects. Table 7 below offers a sampling of responses. Note that the transition from specific to general effects does not appear to be especially challenging, an indication that PCET participation may “ripple out” to affect other classroom practices in other content areas by the same teacher.

Table 7: Sampling of Participant Responses to Teaching Changes Question

Specific Effects	Generalized Effects
• I will emphasize the process as a major component of any project. In first grade, the kids just want to jump in. This will really help me show them how important planning and testing are. • Yes. Mainly for the understanding of engineering. I will use parts of the plant unit since I teach Fast Grow during the year. • The workshop used materials and projects that will be useful in teaching engineering concepts. • As a result of this workshop I will enter my classroom next September more confident in fostering the problem solving process that engineers use in our society. I feel more comfortable facilitating a classroom that is driven by student queries and solutions. • It made me really think about what I will do better next year with the units I teach especially in making connections from the story to the design challenge. It also made me realize how important the discussion after is as far as talking to the students about what worked best and why. • I have always been comfortable teaching the cute fuzzy science topics, like butterfly life cycles. I now feel like I have much more confidence to teach the engineering/technology topics. Even though I need to know more, I feel like this workshop set me on the right path. • In engineering, there isn't always one correct answer and it's okay to fail and try again. This is a somewhat different message than kids generally get in school. With this in mind, I will change the way I teach.	• I especially appreciated the speaker on "women as engineers". I can better visualize and talk to students about the possibility of this kind of future for them. I am reminded of the constructivist approach and noticed the value of the chance for "redesign" on some of these projects. As you know, time is always the issue. • Yes, by implementing the design process I will be asking kids to think more for themselves, create with fewer restrictions the way they believe is best and I believe this will generate a greater interest in the science curriculum. • I will use the engineering design process not only when teaching engineering or other science disciplines as well as adapting it to other curriculum areas. • I will be sure to incorporate the design process into my classroom across the curriculum. • My whole science focus and time is going to change this year so I am very excited to be able to use the model of the design process in my classes this year. I like the idea of the group work, discussion and execution of the challenges that PCET has presented. • Yes. One of the speakers recounted her experience as an elementary school student. After hearing her express her view that she did not get enough science as a child, I was moved. It made a profound impact on me. • I currently use the inquiry method and realize the value of experience-based learning. I will emphasize the engineering process more and discuss its relationship to the writing process. Revision is an opportunity to improve. I also plan to make more connections for my students with the real world.

Participants were asked for additional comments at the conclusion of the survey. These comments were again hugely positive, with the suggestions for improvement almost invariably referring to ways in which the scheduling might be improved.

Table 8: Concluding Open-Ended Comments

Positive	Suggestions
• Thank you for the opportunity to learn the engineering design process and bring it back to my students! • It was a GREAT week! I felt, and still feel, a little overwhelmed by all of it. I appreciate how smart and organized engineers have to be, but as always, I love the teamwork aspect. • This was THE BEST workshop I have ever attended and that includes all the workshops I attended while in the Biotech industry. Bravo to you all! P.S. Do you have a similar type workshop addressing the science frameworks? • This was one of the most useful and helpful workshops I have attended in the area of science. I feel very lucky to have been accepted to attend. • I think the whole idea of EiE is fabulous because most elementary school teachers do not come out of college with any background in engineering, yet this is a part of our state frameworks which we are expected to teach. Having attended the PCET workshop has helped me to feel more comfortable addressing this part of the frameworks in my classroom. It has definitely added to my knowledge base and I have also discovered some good resources that I can look to when engineering/technology questions come up in my classroom! • This was one of only a few workshops that I have felt excited and confident about implementing the curriculum in my classroom. Everything was well thought out and planned. I cannot wait to teach the Bridging unit.	• I think that time could have been used more efficiently throughout the workshop. The teaching that was modeled was not always effective and, more often than not, the teachers did not seem well prepared for their lessons. • I enjoyed the week especially working the 'mentors'. Although I know that the time constraints did not allow us to do hands-on with all of the units I felt the ones that we did not do were glossed over much too quickly. I don't know how that could be remedied and if it is fully necessary but I thought I would point that out to the staff. • Overall the workshop was a valuable experience. However, planning needs some improvement. For example, we only had one fan to test windmills for the 30+ workshop participants. Some materials could have been copied to transparencies so that all of the participants could view them properly. I believe the schedule could have been tightened. • I think each table should have each unit presented whenever we are working. Last year was two weeks for the program. I would have liked to have done all the units (I realize that would be impossible) • I really enjoyed the workshop, but wish that there were units directed more towards first grade material. • The workshop day was too long. By the middle of the week most were too tired. I would have liked to have this done in a long morning session.

Focus Group Findings

At the conclusion of the Tufts workshop, three focus groups were conducted, two by Russell Faux and one by a Museum of Science researcher. The key domains for these focus groups were:

1. Changes in participants' awareness of, and perspectives on, science, technology, and engineering
2. Changes in participants' perspectives on the capabilities of students to carry out engineering activities for important learning gains
3. Perspectives on the implementation of the EiE units in elementary classrooms

Each group comprised 6-8 participants, was recorded with transcriptions made of the recordings. These transcriptions were then analyzed using HyperResearch.

The focus groups tended strongly to corroborate what was found in the survey data above. Participants gained in their awareness of, and appreciation for, engineering. Participants said they thought they EiE materials would work well as a means of conveying engineering thought to students. The learning activities that the participants envisioned for their students would be both engaging and highly generative. The use of these engineering activities was an excellent fit for the elementary classroom, with the strong prevalence of differentiated instruction, the need to encourage students to work together in a hands-on and real-world setting, to reflect collectively, to take risks, and, perhaps most importantly, view failure as an opportunity to learn and improve.

These analyses are summarized in the following table:

Table 9: Focus Group Findings Synthesized

Domain	Finding	Examples
Participant Awareness	Confirming the survey findings, participants reported heightened awareness of the ubiquity and accessibility of engineering thought	• I feel like I have a much better understanding of what engineering is, I feel like I have a much better understanding of what technology is. • I found that I feel I really understand what engineering is now, which I didn't before. • So when you see it from the standpoint of all the different facets of engineering, it really opens the whole world of possibilities to kids.
Expectations for Student Learning	Participants consistently declared that students would benefit from engaging in the EiE	• I've come out of this thinking that this is wonderful for the children, to give them that other component, that creative "use what you know." • I saw presenters for 1st grade that I was sure that those children would not be able to do the things that they were doing with them and, yet, they did them. So I think I've changed in my expectations of my students. I believe that I would think they would be able to do more. • I think the improvement part of the engineering process is probably the most important thing because you just don't say, "Oh, that's it, that's good enough, I'm done." They're always improving. So I think that's really important for kids when they want to say - when they think there's only one right answer, when they get the right answer, that's it, they shouldn't have to think anymore. And that's what I think is one of the most valuable things.
Prospects for Implementation	While some logistical and scheduling problems may persist, participants were confident that the implementations would go forward and be successful.	• I would love to show this to my principal and be like "Well, this is what a real classroom looks like." • Initially if you told me that I would have to have my class make windmills or bridges I would have said, "Are you out of your mind? It's way too over their heads." But they broke it down in such a way that it's feasible. • Everyone should see that wind demonstration. I feel like the whole state of Massachusetts should see that.

Conclusions & Recommendations

It is rather rare in education program evaluation to view such a large and far-flung undertaking be so consistently and strikingly successful as the 2007 PCET summer workshops. The data are clear in underscoring the truly stunning degree to which PCET met its core objectives. Participants spoke effusively and often of the tremendous gains they had made, the revelatory quality of their newfound appreciation for engineering, and the clarity of their understanding on how to introduce EiE materials in their classrooms.

In view of the foregoing, DSRA hesitates to offer recommendations, however, it may be the Project would wish to consider the following:

- Pre-post testing of participants at the summer workshops, rather than relying on self-report data
- As implementations evolve and mature, collect enough student learning data to begin to develop a regression model of effectiveness across different venues
- Move to build something along the lines of FaceBook to support the social networking possibilities coming out the workshops.

Evaluation of the Museum of Science PCET Program

Interim Report

Submitted by Russell Faux, Ed.D.
March 28, 2006

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davisSquare
RESEARCH ASSOCIATES

Executive Summary

The following report presents the methods and findings of three focus groups conducted by Davis Square Research Associates (DSRA) on March 3, 2006 on the effectiveness of the Museum of Science PCET program, with a particular focus on issues surrounding the implementation of the Engineering is Elementary materials. This program is intended to provide participants with access to knowledge and materials to implement innovative engineering content in the elementary grades (roughly 3-5). The purpose of the evaluation was to gather information on the functioning and effects of the program. The data sources for the study were three focus groups.

Key findings include:

1. Participants report that the project builds on pre-existing collaborations among participants as it helps them to learn and implement content and the engineering design process, or EDP.
2. The implementation of the materials is based on a judgment (whether collective or individual) around the fit of the materials and the perceived learning benefits (frequently as measured in the MCAS) versus the time and curricular costs.
3. Effects on both teachers and students include a greater use of the EDP language and problem-solving strategies, as well as improved attitudes toward using more inductive methods.
4. The participant declared desire of strengthening the curriculum is somewhat offset by the their characterization of the limits of the curriculum to accommodate time-intensive innovations.

Sample & Method

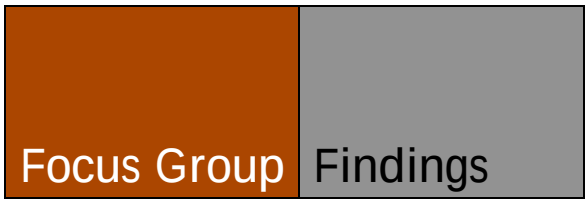
The three focus groups took place one after the other in the afternoon of the March 3, 2006 meeting of PCET participants (N=40). The day was divided into

small group discussions around EIE units that attendees had implemented, or were intending to implement. These discussions were followed by project presentations of two units underdevelopment, with an open discussion of how the units might be improved. With the afternoon there were additional small group discussions and concurrently the three focus groups in succession.

Each focus group lasted from 20 to 30 minutes, with 6-8 participants in each group and each was moderated by Russell Faux. The groups were formed by PCET project management with an eye to putting people together who already had some familiarity with one another. The conversations were recorded and transcribed by an independent transcription service, with the transcripts then imported into HyperResearch for analysis. The focus protocol was a semi-structured series of questions ranging from the motivations for participation, to implementation and learning benefits associable with the lesson. The coding system used to analyze the data is presented in Table 1 below.

The research questions guiding the inquiry were:

- What were the motivations and purposes for participants in the program?
- What did participants encounter as they went about implementing the content and strategies?
- What effects did the participants observe that can be attributed to the use of the materials and strategies?



This section presents the findings of the DSRA analysis of the focus group transcripts. Table 1 provides a synthesis of the analysis by code:

Table 1: Summary by Code

	Motivation: attractors & facilitators (N=37*)	*Collaboration* (N=29)	*Content* (N=24)	*Contexts* (N=50)	*Effects* (N=47)
Summary Statement	Participants cited several attractors (money, timing, PDPs, institutional sponsorships) to the program as well as the desire to gather materials to enliven and improve classroom activities	The project is helped by pre-existing collaborations that support the teachers during the training and into the implementation phase.	Teachers learn new content and then make judgments about implementation based on the perceived fit between the content and the students and curriculum	The curricular and testing contexts do not readily incorporate innovations, yet the teachers are determined to find time or ways of distributing the content across classes and thereby lessen the innovative load	Students use the EDP language and problem solving strategies to address learning challenges in multiple classes; teacher learning is also important as is the strengthening of the teacher professional network

* Refers to the number of instances of this code

Motivation for Participation

Participants cited several attractors (money, timing, PDPs, institutional sponsorships) to the program as well as the desire to gather materials to enliven and improve classroom activities. Some mentioned "this was an area where we needed to improve." No participant spoke of being required to do this because of administrative pressures. The resultant picture is one of participants responding to the attractiveness of the content and the institutions involved, working together as a team, and an array of additional compelling external motivators (e.g., stipends, PDPs, etc.) further supporting the decision to participate.

The following is a sample of what participants said:

- And then like seeing something that's its appealing and it's going to be useful and be hands-on and it's exciting and getting paid for it. I was like "That's unbelievable." I felt like pinching myself.
- Well, when it came through - the application and everything - the first thing was science and technology and how to incorporate that with our MCAS standards and framework. That was a real - what would you call it -- area of need.
- And we had just started out our school - we had done an engineering type project to reach some of the engineering standards 'cause we hadn't been doing that in the past and this was a great way to kind of enhance that in those areas that we all felt we weren't as comfortable in before. So we

wanted to get some ideas on how to enhance that project as well as the science curriculum.
- Well, that attracted me plus I love the Museum of Science, I know that a lot of what they do is - they do good work so that appealed to me also. Getting paid for the time I put in helps too.
- I want to do something to spark up the classroom and this hands-on engineering courses are just so wonderful for me because I get a chance to do things that I know they enjoy and that makes them think more than answering multiple response questions and writing long compositions.

Collaboration

The project is helped by pre-existing collaborations that support the teachers during the training and into the implementation phase. The project's suggestion that teachers come and work together in teams was especially helpful in this regard. There are several key points to be made in this area of the analysis. One is that the program has a strong "grass roots" quality, as no one was mandated to attend. Programs that appeal to the isolated activist teacher, while they may be of great value, are less likely to achieve much dissemination. In contrast, the PCET program builds on pre-existing collaborations with built-in supports for the challenges of learning the new content. In particular, the oft-cited EDP notion of "failing often" can present real emotional challenges to the adult learner. Working collaboratively in this context allowed the participants to share the emotional burden of these challenges.

Second, the implementation phase of the project was said by focus group participants to be assisted considerably by the collaborations built up during the training. Informants spoke of distributing the content, materials, and activities across classrooms, while preserving the EDP language. This will be explored more in the following section, however it is worth noting that the teachers' social networks allowed them to implement the content, modifying the lessons, yet sustaining and reinforcing basic EDP discourse and strategies.

The following is a sample of what participants said:

- Even before this program we're a pretty collaborative group and we really do support each other as a grade level and so a program that feeds into that is very appealing to us.
- I wanted to do it with a partner from my school so I figured that I would take the elementary school one and I could always modify the lessons or modify materials if I needed to. But I was very interested in learning about engineering.
- And we chose not to do that activity just because our kids do a lot of acting and things like that and we thought that to stand in front of the room with a picture wouldn't get to what they knew how to do and then

sort of be a little bit bored by it. So we chose to skip that activity because we just felt, you know what, they have this information already and to stand with a picture and be a tree - it wouldn't maybe interest them as much as some of the other activities would. But I mean overall we loved the unit because it had a lot of engaging activities. But we just chose to not do that one.

- And we were lucky because we could each get a different unit. So I got a wall unit, she got a simple machines unit, she got a wind unit, she got a water unit, so now our school had four different units and we were all able to implement those; whereas if I were just one teacher going back to the school I would only have my one unit that I [would try to implement].
- So, therefore, we could come together and we could kind of work together and I would know that I would have a class of students that I could work with and a teacher that I could work with so we can team together and learn together and see how we could then maybe stretch out and reach out to other 3rd and 4th grade people in the building.

Content & Contexts

The analysis of the focus group transcripts frequently resulting in twin codings of utterances. These codings were "content" and "contexts." It appears to this evaluator that while the content can be easily distinguished from the context of its implementation, the focus group discourse, being more grounded in the practical realities of teaching and learning, made no such distinction. Content was content for teaching and teaching occurs in contexts. These contexts include time, the demands for testing, and the potential of sharing the content with other teachers. The curricular and testing contexts do not readily incorporate innovations, yet the teachers are determined to find time or ways of distributing the content across classes and thereby lessen the innovative load. In brief, the participants learn the new content collaboratively, and then make judgments (frequently collaboratively) about implementation based on the perceived fit between the content, the time available, the capacities of the students and the looming MCAS. In all cases, no matter what the contextual implementation strictures, participants offered nothing but high praise for the qualities of the EIE materials.

The following is a sample of what participants said:

- Yeah, we were talking about [engineering]. I don't think anyone had a really good idea of what an engineer does. So for us this was helpful for us to understand this field that we want to try and push some kids into some day; to be able to answer questions.
- Well, you're doing it for your curriculum and what's required so - like right now I did the windmills experience but I did not do - lesson one, lesson two, I didn't.
- And sometimes it's a matter of time. Looking at an activity, what am I really getting out of it, and how much time's going into it - am I going to

get something, some kind of payback? How far will it advance the understanding of this topic? If it really isn't going to do that, if I'm not going to get that much out of it then it's really not a good use of time because time is the most precious commodity we've got and I can't afford to relax and just enjoy thinking about concepts. I have to get some kind of additional understandings.

- For our particular curriculum we selected whichever units matched our science curriculum topics the best and were this most natural fit to obviously then put engineering into those units in a easy way and a way that made sense. So, for instance, for our particular school and grade level, walls was not something that fit in at all, that unit, to what we teach already. So none of us had the intention this year of ever - we didn't even ask for the walls kit or the walls unit at all because that wasn't the intention at the start of the year. So we really - all of us selected something where we felt it was a natural fit into what we already do within the science curriculum. And maybe two things fit really well, three things fit really well so we are going above the expectation that we'll just do one because we have in science a lot of units that did fit well.

Effects: Teacher, Curricular & Student

The themes of the effects of the program in schools appeared to branch out in three directions: Teacher, curriculum, and students. The teachers became more confident in their understanding of the content. A possible interesting piece of teachers' learning to collaborate better was *not* in evidence here, though it is unreasonable to hold that the teachers became *worse* at collaborating.

The EDP language and strategies began popping up in unanticipated areas. Some of this was the conscious work of collaborating participants, and part was attributed to the students themselves. Participants reported having heard from other, non-participating teachers, about students using the EDP strategies in new contexts (e.g., art). It was thought that students now spoke with their parents about engineering-related issues. In addition, the multicultural aspects of the materials were said to be of particular value, as the standard texts do not always match closely with actual student profiles.

Students began to use the EDP language and problem solving strategies to address learning challenges in multiple classes. Students also benefited from working collaboratively, sharing ideas and developing respect for one another. In this instance, the learning goals of the teacher became coextensive with her character development goals for the students.

The following is a sample of what participants said:

- It's changed the way we think about science.

- I mean I think the kids got a huge amount out of that and they've been able to go home and talk to their parents, they've been writing things down. As soon as I say "windmills," they know “renewable resource” and they know the terminology but I have given up something else and I'm trying, of course, to try to figure out how it's going to get in. And I can sneak it into my class.
- [The arts teacher] came to me and she said, "You know, I can't believe the language that the kids are using when it applies to art." Because they're thinking of some of the same [ideas and strategies].
- You know, we do the talk about diversity but we don't integrate lots of our curriculum around cultural diversity really. And so this has been fabulous. We have a lot of kids from India and so they have [kids] from India too. But the walls one was especially poignant for some of the kids - some of them had actually visited the Great Wall of China or they'd heard their parents talk about it or they had some background knowledge that they could bring to the class themselves, which they don't get a lot of opportunity to do that.
- We use - I use - the word all the time "consensus." Consensus is really important in the design process and I use it in everything we do now so we have a consensus about this. So they have a better understanding about what a consensus is, that you don't always have to agree but you have to come to some kind of agreement in the end.
- I've always been huge on - if you go back to - the kids nowadays do not have the same amount of respect that you feel that you were raised with and I spend a huge amount of time just teaching them manners and how to talk to each other and those things. So that's just something that I focus on from the very first point and that collaborative grouping which makes it a lot easier for them to do these projects together. These are not projects that could be worked on individually but just learning those processes. And I think our school is actually going to be doing special development next year to try to teach all the teachers to have the same skills with their kids because a lot of kids can't work collaboratively. That is a part of these projects so they have to learn the fundamentals.
- And I could explore much more of this than I used to explore before. And I think - I can tell this workshop, it was excellent for me. It opened my mind and my brain to talk to the kids about engineering.
- I feel more comfortable being able to talk to the kids about that and when they give their answers then I'm better able to say whether or not they're on the right track. Before I might just say, "Uh-huh."
- Not thinking of Social Studies again particularly, but we would have used a different vocabulary for it. So a common vocabulary across curriculum I think helps to make those connections with kids.
- I would like to say one of the themes or what I found one of the objectives of the whole program was to make sure that all students felt comfortable with the engineering process. I think before this a lot of girls, for instance, may have felt uncomfortable with the whole engineering design concept

and also it seems as though they're also trying to interest minority groups as well. And I think the program has been very successful in getting the points across to all different kinds of people.

- I think they probably have more of that connection once they go home and then talk to their parents about it and then there's more of a communication that they can have and then maybe they learn more about what their parents do.
- For me it's definitely has an impact on our Social Studies. We teach Ancient Civilizations and so I've started to incorporate more in talking about the technology and engineering of the three ancient civilizations that we teach.
- Now we've looked at it from a different perspective and the kids understand it from a different perspective. More like a problem-solving perspective. Problem-solving, and the redesign piece.
- It's good teaching. It's really good teaching.

Garet, et al. (2002) found through a nationwide study that certain features routinely characterize effective professional development. The three "core" features of effective professional development are (1) a focus on content, (2) opportunities for active learning, and (3) coherence with other learning activities (e.g., learning standards, a broader reform, etc.). Through these core features, the following structures were cited by the AIR team as necessary for the professional development to be effective:

1. Form – teacher networks work best as a context for professional development
2. Duration – longer is better, while traditional “sit and get” formats are rarely seen as effective
3. Collective participation – target groups should be working together

Comparing the findings of the AIR study with the current study of the three focus groups, one can immediately draw clear parallels between PCET project and the first two core features of effective professional development as well as all three of the most effective structures. Participants work together for extended periods of time, sharing and experimenting with challenging content. In short, the PCET program, within the limitations of the current data and with the qualifications arising from implementation, can be readily identified as an embodiment of effective professional development.

The remaining, and somewhat more problematic, core feature of coherence refers to the fit between the content of the professional development and the day-to-day life of the school. In the current case, we have seen that teachers saw the fit as challenging, yet found two ways of working the EIE content into their teaching. First, teachers spoke of picking and choosing the materials that could be used most readily. Second, some teachers spoke of distributing the implementation of the content across classrooms, thus lightening the implementation "load" of any given teacher.

For future research it may be worth considering how the teacher networks evolve over the course of the project and into the future. Do participating teachers change in the patterns or content of their communications with colleagues? Do these changes extend to other, non-participating teachers? What can be determined as to the effects on student learning attributable to the altered communication patterns? If the key factors in building the social networks can be established, then the program may be in a better position to disseminate and scale its efforts across other locales.

References

Garet, M. S. et. al. (2002). "What makes professional development effective? Results from a national sample of teachers." AERJ **38**(4): 915-946.