Evaluation of the Museum of Science PCET Project

Evaluation Report

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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

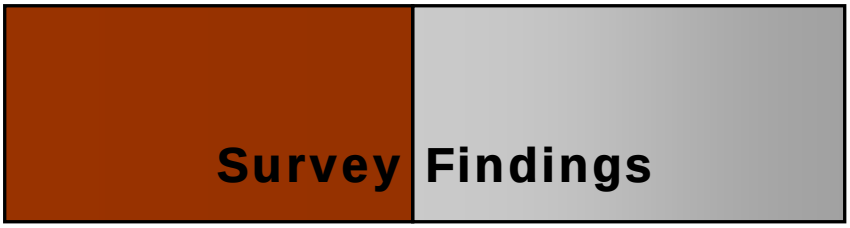
The sample for the survey included all participating teachers (N=120 of 157, a response rate of 77%). A more complete description of the participants will be made available in the Project report. The survey was developed in collaboration with the project leadership and employed mainly Likert scale-type 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.