The Boston Museum of Science BEST Project

Interim Evaluation Report

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Executive Summary

The following report presents the findings from the evaluation research conducted by Davis Square Research Associates (DSRA) on the Boston Museum of Science Bridging Engineering, Science, and Technology (BEST) project, funded by the National Science Foundation, and designed to strengthen the teaching and learning of engineering content in elementary school teacher preparation programs. The current report summarizes the effects of participation in the summer 2010 workshop at the Museum of Science, conducted as a part of the project goal of creating a cadre of faculty leaders whose increased awareness of engineering will assist them in disseminating information and resources necessary for the infusion of engineering content in pre-service teacher preparation.

Key findings include:

- Participants reported strong gains in the attitudes toward their own abilities to teach engineering content
- Participants reported strong gains in their attitudes toward the value of engineering for their students and toward the content area in general
- Participants cited the crowded curriculum as the greatest impediment to implementation
- Participant judgments on statements related to engineering changed to resemble more closely the judgments on the same statements as made by engineering experts.

Sample & Method

The sample for the report is coextensive with the participants in the BEST project (N=21), with the participants being faculty from Massachusetts colleges.

The current report draws on an online survey administered at the conclusion of the workshop. The survey was divided into sections that explored attitudinal changes among participants, a pre-post survey on engineering judgments, and a series of open-ended questions. The attitudinal questions were subdivided into three sections, one on attitudes toward the content, one on self-efficacy around teaching the content, and a third section on the student responses to the content.

The section on engineering judgments compares the respondents' ratings of a series of statements about engineering process, products, and context with the ratings of the same statements done by engineering professionals (university faculty and professional engineers).

The open-ended questions included the rather standard questions on reactions to the workshop and how it might be improved.

The key questions for the survey were:

- How effective has the workshop been in improving the attitudes of participating teachers?
- Have the participants' responses to ambiguous statements about engineering come closer to those of engineering professionals?
- What are the responses of the participants to the workshop?

Survey Findings

The first table below presents the data from the survey items related to the participants' attitudes toward their capabilities at teaching engineering, toward the content area, and toward their confidence in being able to guide students effectively in learning engineering content. All 16 items in this section showed significant (Wilcoxon) gains from pre- to post-test and shrinking standard deviations. This finding means that the workshop was broadly effective at improving the attitudes of all participants.

Table 1: Pre-Post Attitudes

	M: Before	SD: Before	M: Currently	SD: Currently
Enthusiasm for teaching engineering	3.43	1.63	5.52	0.75
Knowledge of engineering for teaching	2.71	1.15	4.76	0.70
Interest in learning more about engineering	3.62	1.56	5.52	0.68
Comfort in using hypotheses in teaching engineering	4.00	1.34	5.43	0.68
Your skills at facilitating engineering explorations	2.86	1.28	5.05	0.59
Your skills at teaching the engineering design process	2.67	1.24	5.14	0.79
Confidence in designing student engineering explorations	2.57	1.29	4.90	0.89
Your ability to present engineering concepts in engaging ways	2.86	1.32	4.71	0.72
Your ability to draw on everyday examples to explain design judgments	2.90	1.26	5.00	0.78
Your ability to spark student interest in engineering	2.95	1.36	5.10	0.70
Your confidence that students will enjoy learning about engineering	3.19	1.44	5.29	0.72
Your ability to understand student misconceptions in engineering	2.76	1.41	4.67	0.97
Your ability to anticipate student misconceptions in engineering	2.62	1.56	4.29	1.31
Your expectations for student interest in engineering	2.76	1.22	4.76	0.77
Your expectations for student learning in engineering	2.81	1.29	4.81	0.75
Your expectations for student attitudes toward engineering	2.71	0.96	4.95	0.74

Breaking out the above into three domains, namely, attitudes toward content, self-efficacy, and attitudes toward student learning of engineering, DSRA found the pre-post changes were all significant (paired samples t test) and that the gain scores were narrowly distributed, meaning all participants made very strong gains.

Note also that the effect sizes are quite large, meaning that the magnitude of the gains was of a substantial order.

Table 2: Pre-Post Gains by Domain

	M: Before	M: Currently	M: Gain	Effect Size
Attitudes toward content (Items 1-4)	13.76	21.24	7.48	.74
Self-efficacy (Items 5-10)	16.81	29.91	13.10	.80
Attitudes toward student learning (Items 11-16)	16.86	28.76	11.91	.76
Overall	47.43	79.91	32.48	.79

When asked about the barriers to the implementation of more engineering content, participants reported higher mean values for the "crowded curriculum" and "not enough resources." The "lack of self-confidence" was seen as very low, confirming what was found in the above items on attitudinal shifts.

Table 3: Barriers to Implementation

	Mean	Std. Deviation	Minimum	Maximum
Crowded curriculum	4.67	0.59	3	5
Not enough resources	3.42	1.07	1	5
Student disinterest	2.56	1.32	1	5
Lack of administrative support	2.47	1.19	1	5
Lack of self-confidence	1.85	0.99	1	4

Two of the above items, "crowded curriculum," and "lack of self-confidence," were found to be statistically significant (Kolmogorov-Smirnov), indicating a stronger-than-expected consensus around the mean values. In this case, the finding of significance indicates that the teachers were generally united in declaring the crowded curriculum to be an important barrier and the lack of self-confidence to be relatively unimportant as a barrier to implementation. In contrast, the participants' assessments of the other three items were more or less normally distributed. This finding suggests that for the perceived barriers to implementation vary somewhat from participant to participant for these three items.

Engineering Judgments

In the following section DSRA examines the extent to which the responses of workshop participants to statements about engineering changed from the pre- to post-test. There are two points of comparison to be made here. First, the differences between the expert judgments at the pre-test will be conducted, followed by the differences between experts and participants at the post-test. This method is rather different from the typical pre-post model, and we hold that this represents something of an innovation in the evaluation of professional development.

The engineering judgments instrument is broadly divided into three domains, process, context, and process, and the following analysis will be presented in the intended order. DSRA notes that the instrument has not undergone any confirmatory factor analysis as of this writing, though this remains a longer-term goal (once an adequate N has been developed).

The following table shows the results for the 19 items related to process. The values in the final column represent the difference between the expert and faculty means (M), a value that one would expect to see shrink from pre- to post-test as the faculty judgments come to more closely approximate those of engineering experts. The statistics used were the independent samples t-test for all between-groups comparisons. The asterisk in the "Role" column means that DSRA found a significant difference between the faculty judgments and those of the experts. In the "Expert-Faculty" column a positive value indicates that the faculty tended to report lower judgments than those of the experts, while a negative value indicates that the faculty reported a higher value than those of the experts.

Table 4: Engineering Process Statements

Item	Role	N	M	SD	Expert-Faculty
1. Process: An engineer should test materials before creating a design that uses those materials.	Expert	95	7.41	2.537	
	Faculty – Pre*	24	8.67	1.810	-1.260
	Faculty – Post*	20	8.70	2.003	-1.290
2. Process: Analysis of data helps engineers make informed design decisions.	Expert	95	9.57	0.767	
	Faculty – Pre*	24	9.29	1.876	0.280
	Faculty - Post	21	9.57	0.676	-0.001
3. Process: Engineering design is an iterative process.	Expert	93	9.24	1.402	
	Faculty – Pre*	24	8.04	2.836	1.200
	Faculty - Post	20	9.55	0.759	-0.310
4. Process: Engineering failures are an important source of engineering knowledge.	Expert	93	9.32	1.124	
	Faculty - Pre	24	8.96	1.944	0.360
	Faculty – Post*	21	9.67	0.658	-0.347
5. Process: Engineers don't need to know much about math.	Expert	94	2.06	1.983	
	Faculty - Pre	24	1.83	2.099	0.428
	Faculty - Post	21	2.67	2.456	0.536
6. Process: Engineers often cycle through the engineering design process again and again as they work on a single problem.	Expert	94	9.02	1.368	
	Faculty - Pre	24	9.00	2.085	0.020
	Faculty - Post	21	9.33	0.966	-0.313
7. Process: Engineers often work in teams.	Expert	95	9.34	0.974	
	Faculty - Pre	24	8.79	1.888	0.550
	Faculty - Post	20	9.20	1.152	0.140
8. Process: Engineers typically work alone.	Expert	95	2.18	1.304	
	Faculty – Pre*	24	2.50	2.588	-0.320
	Faculty - Post	20	2.10	1.619	0.080
9. Process: Because engineers use science and math, they almost always get the same answer.	Expert	95	2.29	1.719	
	Faculty – Pre*	24	2.79	2.502	-0.500
	Faculty - Post	21	2.67	2.153	-0.377
10. Process: Engineers use science in their work.	Expert	95	8.97	1.410	
	Faculty - Pre	24	8.42	2.765	0.550
	Faculty – Post*	21	9.52	0.680	-0.554
11. Process: Feedback is important to the engineering design process.	Expert	94	9.53	0.743	
	Faculty - Pre	24	9.21	1.865	0.320
	Faculty – Post*	21	9.81	0.402	-0.280

Item (con't)	Role	N	M	SD	Expert-Faculty
12. Process: Innovation and creativity are important to the engineering design process.	Expert	95	9.24	1.327	
	Faculty – Pre*	24	8.58	2.263	0.660
	Faculty - Post	21	9.43	0.978	-0.189
13. Process: More than one design may be acceptable for a given problem.	Expert	95	9.48	0.849	
	Faculty - Pre	24	9.08	1.886	0.400
	Faculty – Post*	21	9.71	0.644	-0.234
14. Process: Once a design has been created using the engineering design process, it is a completed design.	Expert	95	2.26	1.702	
	Faculty – Pre*	24	3.13	2.290	-0.870
	Faculty - Post	21	2.86	2.651	-0.870
15. Process: Testing to failure is important because you can apply the knowledge you gained to your next design.	Expert	94	8.76	1.464	
	Faculty - Pre	24	8.33	2.479	0.430
	Faculty – Post*	21	9.71	0.717	-0.954
16. Process: There is always a definitive right answer.	Expert	95	1.71	0.955	
	Faculty - Pre	24	2.63	2.123	-0.920
	Faculty - Post	21	1.86	1.740	-0.147
17. Process: There is usually one best way to solve a problem.	Expert	95	2.97	2.176	
	Faculty – Pre*	24	4.04	3.329	-1.070
	Faculty - Post	21	2.62	2.037	1.421
18. Process: Thinking of many different ideas for a design is usually a waste of time.	Expert	95	1.78	1.664	
	Faculty - Pre	24	2.00	2.359	-0.220
	Faculty – Post*	21	1.24	0.539	0.542
19. Process: Engineers from many different disciplines work together to create a product.	Expert	94	8.91	1.333	
	Faculty – Pre*	24	8.21	2.449	0.700
	Faculty - Post	20	8.95	1.849	-0.040

The following table summarized the movement toward or away from statistical significance by item. Note that on 4 of the process items on the pre-test, participants expressed judgments similar to those of experts, with this number moving to 12 of 19 on the post-test. This is a very good finding. Somewhat more puzzling is the movement away from expert judgments on six of the 19 (32%) items. On all but Item 18 the faculty tended to overvalue the opinion expressed in the judgment, relative to the experts.

Table 5: Changes in Engineering Process Judgments

Observed Change	Item Numbers	Comment
No significant differences at pre- or post-test	5, 6, 7, 16	On these items the participants expressed judgments very similar to those of the experts.
Significant differences at pre-test only	2, 3, 8, 9, 12, 14, 17, 19	On these items the participants made significant gains in making judgments similar to those of the experts
Significant differences at post-test only	4, 10, 11, 13, 15, 18	On these items the participants moved away from expert judgments
Significant differences at pre- and post-test	1	On this item the participants began and remained distant in their responses to this item.

Looking at the five statements regarding the context of engineering, participants varied significantly from experts in all five on the pre-test, then on just two of the five on the post-test. This is a sharply positive finding, and one that supports the judgment of effectiveness for the workshop. On the other two items for which the participants varied from the experts on the post-test, participants over-valued the extent to which engineering has changed society and under-valued the need for trade-offs in engineering design.

Table 6: Engineering Context Statements

Item	Role	N	M	SD	Expert-Faculty
Context: Engineers often think about criteria and constraints.	Expert	95	9.52	0.836	
	Faculty – Pre*	24	8.08	2.842	1.440
	Faculty – Post	21	9.62	0.590	-0.099
Context: Balancing different design variables is an important part of engineering.	Expert	95	9.63	0.773	
	Faculty – Pre*	24	8.25	2.289	1.380
	Faculty - Post	21	9.76	0.436	-0.132
Context: Engineering has changed society.	Expert	95	9.75	0.699	
	Faculty – Pre*	24	9.29	1.876	0.460
	Faculty – Post*	21	9.95	0.218	-0.202
Context: Trade-offs are inherent in engineering design.	Expert	95	9.54	0.783	
	Faculty – Pre*	24	7.83	2.632	1.710
	Faculty – Post*	21	8.43	2.135	1.111
Context: Problem identification is critical to the engineering design process.	Expert	95	9.48	1.184	
	Faculty – Pre*	24	8.83	2.514	0.650
	Faculty - Post	21	9.62	0.669	-0.139

On the final section of the engineering judgments survey, participants varied from experts on 5 of the 7 items on the pre-test and on just two items on the post-test. Again, this is an excellent finding and a clear indication of the high quality of the BEST workshop. Combining this with the products section, DSRA finds a significant improvement on 8 of 12 items constituting these two domains, and with the inclusion of the first section, on 20 of 31 items.

Table 7: Engineering Products Statements

Item	Role	N	M	SD	Expert-Faculty
Products: Technology is rarely a process.	Expert	95	2.11	1.594	
	Faculty – Pre*	24	2.38	2.551	-0.270
	Faculty - Post	20	1.60	1.046	0.510
Products: Technologies usually require the use of electricity.	Expert	95	3.29	2.324	
	Faculty – Pre*	24	4.46	2.874	-1.170
	Faculty - Post	21	2.71	2.004	0.576
Products: A technology can be made up of multiple systems.	Expert	93	9.41	0.875	
	Faculty – Pre*	24	8.83	1.993	0.580
	Faculty – Post*	21	9.62	0.590	-0.209
Products: Technologies are primarily objects that use electricity.	Expert	94	2.35	1.638	
	Faculty – Pre*	24	3.33	2.353	-0.980
	Faculty - Post	21	1.90	1.546	0.445
Products: Most things in your home were designed by engineers.	Expert	95	8.26	2.184	
	Faculty – Pre*	24	7.33	3.046	0.930
	Faculty - Post	21	8.81	2.316	-0.550
Products: All technologies are physical objects.	Expert	95	1.79	1.328	
	Faculty - Pre	24	2.71	2.562	-0.920
	Faculty – Post*	21	2.86	2.555	-1.067
Products: The definition of technology goes beyond electronics.	Expert	94	9.73	0.571	
	Faculty - Pre	24	9.38	1.861	0.350
	Faculty - Post	21	9.71	0.561	0.016

Open-Ended Responses

Workshop participants were asked to describe the workshop in just a few words. The descriptions are very positive and very consistent across all responses. Participants clearly found the workshop well-organized, informative, useful, and inspiring. The following are a sample of what respondents wrote:

- The BEST workshop was excellent: good collaboration, good cross-disciplinary and cross-institution discussion, good modeling of good practice
- Catalytic; renewing
- Relevant information; easily utilized
- Informative, collaborative, motivating and eye-opening
- Thought provoking
- The workshop was very interesting and thought provoking. It has application for hands-on learning for all students. It was also fun!
- It was very interesting and offered a chance to meet with community colleges, state universities, and Museum of Science EiE individuals.
- Great information
- Wonderful, informative, communication among colleagues
- Good reminder of the use of hands on problem solving in the classroom
- Makes me want to be an elementary school teacher!

When asked about how the workshop might have helped the participants grow as a teacher, the participants generally mentioned either content or pedagogy. References to content tended to describe the engineering content as something that could be incorporated into the curriculum, while the references to pedagogy tended to underscore the importance of inquiry. The following table presents a sample for each domain of responses.

Table 8: Reported Effects on Participants

Content	Pedagogy
I have been trying to develop a curriculum for our Life Science course and this has given me information and perspective that will be very helpful to complete the work. It helped me see more connections between my curriculum and the teaching of engineering. I learned about engineering design. Realized the similarity to the scientific method and that I could teach ED. BEST has articulated some very powerful methods for illustrating to my students, the relevance of Biology and it's connection to technology and society. I also knew about helping preservice elementary teachers with biology and chemistry content, but learned using engineering is a more appropriate way to help future teachers and the elementary students they will have in the future.	Modeled good teaching practice, and good learning practice. Created opportunities to reflect on how we teach and how we learn. Created opportunities for dialogue with our two- and four- year IHE colleagues about the education we provide for the students we share It has made me think of incorporating more problem solving and exploratory activities in class (not just lab, but also lecture). It has also presented a challenge - how to integrate engineering design principles into non-majors and majors-level intro bio classes (I love challenges). Another way to think about inquiry. Reinforcement of hands on activities

Finally, when asked about whether the participants anticipated any effects on student learning, the respondents were unanimous in declaring the great value of engineering for their students. Responses often mentioned the engineering design cycle as a replicable, generalizable model of learning and understanding content. There were also scattered mentions of the value of having an awareness of engineering in general, and of the inspirational effects of using EiE in their classes. The following is a sample of what the faculty wrote:

- They sure will. They can demonstrate the skills they gain in the program to help classroom children appreciate the importance of bridging engineering, science and technology at an early state, and hopefully choose career paths in engineering.
- Yes. I will be able to incorporate engineering principles into non-bio major courses, which I would not have even attempted before.
- YES! We will continue the dialogue (within our program, across disciplines within our institution, and with our partner 4-year university to strengthen the education our students receive and to align what we do to a greater degree. Specifically, we are already reviewing our education

curriculum and adding an additional section of one foundation course; and the EDU faculty colleague from our partner 4-year IHE has agreed to join our EDU program advisory board.

- Yes. At a minimum, exposure to more hands-on learning activities should facilitate deeper learning. In addition, exposure to engineering basics should help them become more effective citizens (basic liberal arts/STEM philosophy).
- Yes, hopefully I can convey this enthusiasm and confidence to them
- Yes. The Engineering Design process is an excellent inquiry-based cycle that aligns with my teaching goals.
- Students will benefit from hands-on learning, using critical thinking skills and teamwork. They can encourage their students to think of careers in engineering.
- Yes, by examining the relationship between Science and Engineering. I will provide them opportunities to design experiments using concepts we cover in class.
- Definitely, they will be better able to help elementary students understand science inquiry and scientific processes thru the use of engineering curriculum specifically targeted for the audience.
- Yes, They love to construct and solve problems. It's a perfect way to learn engineering concepts.
- Yes, if I can fit it in, which I intend to, I think it will enhance their understanding of the content matter and decrease their fear of science. In addition, I think it will build their confidence in problem solving and engineering.

Conclusions & Recommendations

The above data clearly show that the Museum of Science, Boston, summer workshop, offered as a part of the BEST project, was highly effective at improving the attitudes of the faculty participants toward teaching engineering. While the crowded curriculum is likely to persist as a challenge, the workshop participants reported significant gains in the attitudes toward their own abilities to teach engineering, toward the field of engineering in general, and toward the learning benefits that would be made possible to students exposed to engineering content.

The engineering judgments survey showed broad and pervasive gains on roughly 2/3 of the items. The distribution of those items was fairly smooth over all three domains of the survey, with participants consistently coming to express judgments closer to those of engineering experts. This is a remarkably good finding, and one that the BEST project leaders should find heartening.

Taking into consideration the above, DSRA recommends the following:

- That the project consider doing follow up survey work to determine whether there are any enduring effects of participation
- That the project examine closely those survey items on which participants varied significantly from experts on the post-test. It may be that the concepts underpinning these statements are being miscommunicated or misinterpreted by participants.