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Bridging Engineering, Science, and Technology (BEST) for Elementary Educators

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Bridging Engineering, Science, and Technology (BEST) for Elementary Educators

Introduction: What is the need?

This paper will discuss the Bridging Engineering, Science, and Technology (BEST) for Elementary Educators program developed by the Engineering is Elementary team at the Museum of Science, Boston. Designed to help college faculty integrate engineering content into courses taken by preservice teachers, the BEST program provides a model for how to organically transform teacher preparation to include engineering and technology content.

To increase the technological literacy of all our citizens, engineering and technology need to be effectively taught in schools K-12, but especially in the early elementary school years. Although a growing number of teacher preparation programs in the United States are increasing mathematics and science requirements for future elementary teachers, the instruction that these teacher candidates receive in engineering and technology is almost non-existent. Developing teachers' understandings of technology and engineering, as well as their close connections to science and mathematics, is critical if they are to prepare their students for the 21st century Community colleges are a key place to impact preservice teacher preparation. It is estimated that one-fifth of future teachers begin their studies at community colleges[1], and approximately 40% of teachers in the United States have completed some or all of their math and science coursework at a community college[2].

Technology and engineering are new fields at the elementary level. However, this is where such education needs to start. Just as it's important to begin science instruction in the primary grades by building on children's curiosity about the natural world, it is important to begin technology and engineering instruction in elementary school by fostering children's natural inclination to design and build things, and to take things apart to see how they work[3]. Beginning in elementary grades is also important since it is before students develop many of the stereotypes that so often discourage girls and minorities from pursuing courses and careers in technical fields[4]. It is during primary school that students establish first impressions of possible career options[5]. Finally, at all educational levels, technology projects can help make mathematics and science content relevant to students by illustrating these subjects' application in real-world projects[6].

To build the foundation for the next generation of technicians and engineers, we need elementary teachers who are introducing their students to technology and engineering topics in the classroom. However, we cannot expect teachers to confidently and competently teach content that they themselves have not learned. Community colleges play a crucial role in educating elementary teachers. Total enrollment in community colleges has increased from 5.7 million in 2000 to 6.2 million in 2005 and 7.1 million in 2009[7]. As of 2009, enrollment at community colleges comprised 40% of all students enrolled in US institutions of higher education[8]. Community colleges report that 5.5% of their college freshmen have expressed interest in teaching elementary education—this translates to a potential of 390,500 elementary teachers per year[9]. The majority of these students will complete their general education requirements at the community college before transferring to a 4-year university to complete their degree. Since these students will take their required science courses at the community college, these courses are where faculty can develop education students' understandings of engineering and technology. Upon transferring to a 4-year university, preservice teachers' confidence and skills in teaching engineering and technology can be supported and augmented in Science Methods courses and Teacher Practicum experiences.

What is BEST?

The Bridging Engineering, Science, and Technology (BEST) for Elementary Educators project aims to increase preservice teachers' perceptions of and confidence in teaching STEM in the elementary classroom in Massachusetts. Massachusetts' curriculum frameworks state that "approximately one-quarter of PreK-5 science time should be devoted to technology/engineering"[10], and elementary students are assessed on technology and engineering standards through a state-wide exam in fifth grade. The BEST grant works with faculty from four Massachusetts community colleges and their 4-year transfer partners to implement engaging engineering and technology content in preservice teacher preparation courses. Thirty-five faculty members from these Massachusetts colleges are currently involved in the BEST grant, impacting approximately 750 students each year.

Our work on an earlier NSF-funded grant called Advancing Technological Literacy and Skills (ATLAS) of Elementary Educators indicated that a key place to influence preservice engineering education is in education students' required science courses. To this end, the BEST grant works with both education and science faculty. Teams of science and education faculty participate in an annual summer professional development workshop focused on engineering and technology content and related pedagogy. They then develop plans for course modules that integrate engineering concepts and activities, implement their modified courses that fall semester, and assess student impact. During the midyear meeting in January faculty present their labs and activities to colleagues, receive feedback, and brainstorm successful strategies for implementation in the spring semester.

Introductory course content in both science and education courses overlaps greatly from college to college. Such convergence promotes the sharing of engineering modules, which facilitates dissemination and adoption by other faculty and institutions. Course modules have been developed for life science, physical science, education methods, and other related education courses. Despite the varying topics, all of these modules engage students in engineering activities, model problem-based pedagogical strategies, and highlight the connections between science, technology, engineering, and math.

In addition to organizing biannual meetings and facilitating peer-to-peer interaction between faculty, the BEST grant staff provide professional development opportunities for inservice teachers. These regional workshops are held in areas of Massachusetts close to the BEST colleges. The workshops are designed to introduce veteran elementary teachers to engineering and technology content as well as to strategies for implementing these topics in the elementary classroom and provide curricular materials for teachers.

Because the workshops are held near the BEST colleges, we are able to recruit classroom teachers from schools that provide practicum experiences for the BEST education students. Our goal is to ensure that education students will first experience engineering and technology content in their college courses and then have that content reinforced by engaging in a practicum experience with a veteran teacher who is implementing engineering activities and modeling problem-based pedagogical strategies in the elementary classroom. BEST faculty often attend the teacher workshop local to their region and, on occasion, have invited their education students as well. For example, in April 2012, faculty from Middlesex Community College in Bedford, MA and from Salem State University in Salem, MA invited elementary education students to the engineering professional development workshop held for the northeast region of the state. Four elementary teachers from the Lane Elementary School in Bedford were also at the workshop. These veteran teachers met and worked with the education students during the engineering activities, and after the workshop they contacted their principal to volunteer as mentor teachers for the Middlesex students. BEST is working to foster collaboration between community colleges, 4-year colleges, and local elementary schools.

What does successful implementation look like?

The BEST grant encourages and supports the many stakeholders involved in preservice teachers' experiences along the continuum of their postsecondary education: from community college to 4-year university to elementary classroom. An ideal example of the BEST model in action can be seen from activities taking place in the northeast region of the state. Dr. Rebecca Westphal, a science professor at North Shore Community College (NSCC), has implemented different engineering modules in both of her Introductory Biology courses. One is based heavily on activities introduced during professional development provided by the BEST grant staff and covers the topics of ecosystems, environmental engineering, and the technologies designed to control oil spills. The other is original to Dr. Westphal and centers on the physics of locomotion of aquatic organisms, biological engineering, and biomimetic technologies such as fin design. Dr. Westphal has implemented the oil spill module several times, but the aquatic locomotion module is new. She kept the oil spill module in one course, and is piloting the new module in her other course. Dr. Westphal is also presenting the pilot module at the January midyear meeting to faculty from the other BEST colleges, who will engage in the module's engineering activities as learners, ask questions about her development process and the efficacy of implementation, and provide feedback. Depending on the topics covered in each professor's syllabus, this new module may be implemented in multiple colleges in future semesters.

Dr. Westphal's modules may be her students' first exposure to technology and engineering at the college-level. If her students then move on to NSCC's 4-year transfer partner, Salem State University (SSU) they will have more chances to experience engineering content in their courses. Patricia Bade, a science methods lecturer in the Childhood Education Department at SSU and Dr. Deborah Mason-McCaffrey, a physics professor in the Chemistry and Physics Department at SSU both teach the same engineering module to their students, a module centered on variances in atmospheric density, aerospace and aeronautical engineering, and different technological designs of parachutes. After students have participated in a number of preparatory engineering activities and experienced background content important to the unit in both courses, the two professors bring their classes together to engage in the engineering challenge of designing parachutes that meet specific criteria. In this experience, students from both courses collaborate and learn from each other.

Dr. Bade explains that the experience with the physics students helps "demystify" certain aspects of the content for her students because they can consult the physics students when they have questions about the content. This experience helps the education students feel more comfortable doing engineering and gives them the confidence to believe engineering can be accessible to their future elementary students. Dr. McCaffrey asserts that the hands-on collaborative component of the engineering challenge adds to her physics students' learning as well—the physics students benefit from the education students' abilities to foster productive and supportive collaboration in groups. In order to further reinforce engineering content and pedagogy, Dr. Cleti Cervoni, BEST professor and chairperson of the Childhood Education Department at SSU, works to ensure that the students from Dr. Bade's course are later placed in practicum experiences with teachers who have been trained in engineering and technology content and problem-based pedagogy. There are many players involved in an elementary teacher's preservice preparation, but when there is fluid communication and collaboration between them all, new teachers enter the classroom confident that they can teach engineering and technology to their students, and committed to the importance of doing so.

How do we measure success?

Measurement of the BEST project's success has centered on two main areas that reflect the overarching goals of the grant:

- How helpful does the faculty find the grant activities to be, in particular the professional development opportunities? How effective are these activities in convincing faculty to integrate engineering and technology into their courses?

- Does faculty's integration of engineering and technology into their courses change student perceptions of and attitude towards engineering and technology?

Project staff have worked with Davis Square Research Associates (DSRA) to collect data from project participants. The first area of interest has been measured through a series of workshop evaluation surveys that faculty complete after each summer workshop. Although these surveys have changed slightly during the three years of data collection (academic years 2010-2011, 2011-2012, and 2012-2013), they feature similar questions. They explore participants' attitudinal changes towards engineering and technology, their own skills at teaching these topics, and their expectations for student learning. The surveys also include questions regarding participants' reactions to the workshop, how likely participants were to attend a similar workshop, and how likely they would be to recommend attending to a colleague. DSRA has to date conducted two of three planned faculty focus groups (one in each academic year of the grant). These focus groups have investigated the extent to which faculty's perceptions of and attitudes towards teaching engineering and technology have changed as a result of participating in the BEST project, as well as the remaining barriers that continue to impede implementation of these topics into their courses.

The second area has been assessed through a pre- and post-survey that measures students' level of agreement with a series of statements about engineering (presented item-by-item in Table 1 below).

Table 1

	#	Engineering Statements
Process	Q1	An engineer should test materials before creating a design that uses those materials.
	Q2	Analysis of data helps engineers make informed design decisions.
	Q6	Engineering design is an iterative process.
	Q7	Engineering failures are an important source of engineering knowledge.
	Q9	Engineers don't need to know much about math.
	Q10	Engineers often cycle through the engineering design process again and again as they work on a single problem.
	Q11	Engineers often work in teams.
	Q13	Engineers typically work alone.
	Q14	Because engineers use science and math, they almost always get the same answer.
	Q15	Engineers use science in their work.
	Q18	Feedback is important to the engineering design process.
	Q20	Innovation and creativity are important to the engineering design process.
	Q22	More than one design may be acceptable for a given problem.
	Q24	Once a design has been created using the engineering design process, it is a completed design.
	Q28	Testing to failure is important because you can apply the knowledge you gained to your next

		design.
	Q30	There is always a definitive right answer.
	Q31	There is usually one best way to solve a problem.
	Q32	Thinking of many different ideas for a design is usually a waste of time.
	Q34	Engineers from many different disciplines work together to create a product.
Context	Q37	Engineers often think about criteria and constraints.
	Q38	Balancing different design variables is an important part of engineering.
	Q39	Engineering has changed society.
	Q42	Trade-offs are inherent in engineering design.
	Q45	Problem identification is critical to the engineering design process.
Product	Q46	Technology is rarely a process.
	Q47	Technologies usually require the use of electricity.
	Q48	A technology can be made up of multiple systems.
	Q49	Technologies are primarily objects that use electricity.
	Q50	Most things in your home were designed by engineers.
	Q54	All technologies are physical objects.
	Q55	The definition of technology goes beyond electronics.

A group of 94 experts in engineering and engineering education from across the US (including university professors and professional engineers in industry) rated their level of agreement with these statements. The statements can be sorted into three main categories: statements about (1) the engineering design process, (2) the larger context into which engineering and technology fit in society, and (3) the technological products that are the result of engineering. The instrument is intended to reveal whether the judgments expressed by the student participants more closely approximate those of experts after the student has participated in a course including engineering and technology topics. The students rate their agreement with these statements on a 1-10 Likert scale, with 1 signifying strong disagreement and 10 signifying strong agreement. Of the 55 original statements, only the 31 that showed statistical significance between engineering experts' and novices' judgments were retained for the duration of the grant.

Findings

The findings from BEST can be divided into the three years of the grant: academic years 2010-2011, 2011-2012, and 2012-2013. Each year begins in June with the multi-day professional development workshop for faculty and ends the following May with the final collection of the spring student data.

June 2010-May 2011

Faculty Professional Development

The kick-off to the BEST grant was a 4-day workshop held in June 2010. In an online survey administered at the conclusion of the workshop, faculty participants answered questions that explored their attitudes around engineering and technology: towards the content, self-efficacy around teaching the content, and anticipated student responses to content. They also completed a pre-post survey that compared their judgments on statements related to engineering process, products, and contexts to judgments on the same statements done by engineering experts. The survey also included a few open-ended questions that addressed standard workshop evaluation such as reactions to the workshop and how it could be improved.

The first 16 items of the survey explored participants' attitudes around engineering and technology. All of these items showed significant gains from pre- to post-test and shrinking standard deviations. These strong gains in their attitudes toward their own abilities to teach engineering content as well as in their attitudes toward the value of engineering for their students demonstrate the workshop's effectiveness in impacting attitudes. Participant judgments on the engineering statements changed to more closely resemble the judgments made by engineering experts, with 20 of the 31 statements showing significant improvement. Participants cited the crowded curriculum as the greatest impediment to integrating engineering into their curriculum.

When asked to comment on the quality of the workshop, faculty descriptions were very positive. Examples include:

- *The BEST workshop was excellent: good collaboration, good cross-disciplinary and cross-institution discussion, good modeling of good practice*
- *Wonderful, informative, communication among colleagues*
- *Relevant information; easily utilized*

When asked if the workshop had helped faculty develop as teachers, the responses were mostly centered on either content or pedagogy:

- [content] *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.*
- [content] *It has helped me see more connections between my curriculum and the teaching of engineering.*
- [pedagogy] *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 colleagues about the education we provide for the students we share*

Faculty members were unanimous in declaring the value of engineering integration for their students in following semesters. When asked whether they anticipated any effects on students learning, responses included:

- *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! 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.*
- *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.*

Faculty Focus Group

In March 2011 DSRA conducted a focus group interview with five faculty members from Middlesex Community College. All five of the faculty teach courses aimed at future elementary and early childhood educators. The interview focused on (1) preparation for the engineering and technology lessons/activities, (2) implementation of the content and its effects on education students, and (3) prospects for dissemination. The participants reported that the engineering and technology curriculum materials and resources provided by the BEST professional development were easy to prepare and implement in their courses, and readily fit into their existing curricula. Even faculty self-identified as having weak backgrounds in STEM content reported being able to overcome their anxieties and acquire the confidence needed to implement the engineering and technology content using the resources they acquired in the June professional development. One faculty member expressed how prior to participation in the BEST grant she had not been predisposed to teach STEM content in her education classes, but that BEST had changed her perspective: "I didn't like doing math or science, quite frankly, because I didn't think I knew how to do it. And implementing it has shown me how much involved science, math, and technology are in just about everything."

The faculty felt that the preservice teachers in their courses had responded very positively to the engineering and technology content, and stated that the preservice teachers had had positive experiences when they implemented an engineering unit in their field placements. They reported that the inservice teachers supervising the preservice teachers' field placements supported the implementation of the engineering unit and felt that it was successful. They also referenced their students' abilities to overcome preexisting aversions to STEM topics:

- *My students did a waterwheel and it was really interesting to watch them because they thought they were getting behind everybody else because theirs didn't work right away. I think they learned more by it not working right away because they had to go back to the drawing board and try to figure it out, "Okay, what do we do now?"*
- *My students were like, "How are we going to bring this into our classrooms?" and "This is going to be difficult." And they came back and they said it was marvelous. They absolutely loved it.*

- *And what we're doing here I think in early childhood [education] is that we're hopefully taking away that fear and to enjoy it.*

DSRA found that the faculty were unsure about the feasibility of further dissemination of engineering within the college. They explained that many of the college courses were taught by adjunct faculty, who were torn between multiple competing priorities (often holding positions at other schools during the day and coming to the college to teach in the late afternoons and evenings). They explained that this frequent coming-and-going leads to a weak faculty network, which is not conducive to dissemination or collaborative professional development. However, faculty did express confidence in the grassroots person-to-person transferal of information, and thought that enthusiasm for engineering would spread in an almost viral manner—dependent on individuals presenting the case to other faculty members who they thought would be potentially receptive.

Course Integration

Students in both the Fall 2010 semester and Spring 2011 semester were given the survey of 31 engineering statements both before and after experiencing the integration of engineering and technology in their course.

Eleven faculty and 183 students from six colleges participated in the student survey in Fall 2010. Table 2 shows the pre-post changes in student responses, with the responses summarized by college and by category. Middlesex Community College (MCC) has no post- data in the table because students did not complete the post-test. Student responses were measured against the responses of engineering experts, as explained in the previous section. In the pre-test, DSRA found 133 instances where student responses differed from the engineering experts, out of a total of 186 possible instances of difference (72%). In the post-test, DSRA found 51 instances of difference of a total of 155 possible instances of difference (33%). The instances of disagreement with the experts dropped by over half after experiencing courses integrated with engineering and technology. This is a significant improvement.

The strong student gains show that the participating faculty were generally quite effective in helping their preservice teachers develop a more accurate sense of what engineering is and of how it fits into the larger world. However, there is substantial variation in student gains between colleges—which is most likely due to faculty's different implementation strategies and engineering activities.

Table 2

College	Engineering Design Process (N=19)		Engineering's Larger Context in Society (N=5)		Technological Products of Engineering (N=7)	
	Pre-	**Post-**	**Pre-**	**Post-**	**Pre-**	**Post-**
Fitchburg	17	13	5	5	7	5
Massasoit	13	3	3	2	7	4
MCLA	6	0	2	1	6	1
MCC	10		5		7	
Salem State	13	1	5	1	7	1
Westfield	10	13	3	0	7	1
Total/Total Possible	69/114	30/95	23/30	9/25	41/42	12/35

277 students from six colleges participated in the student survey in Spring 2011. To more specifically identify changes in student attitudes towards engineering and changes in preservice teachers beliefs about teaching engineering, two new sections were added to the post-test. In the first additional section respondents were asked to rate eleven statements about their knowledge of and attitudes toward engineering before and after taking the integrated course. In the second additional section respondents who self-identified as preservice teachers were asked to rate seven statements regarding their expectations for using engineering in their work with children. Ratings for both sections ranged from 1 (very low/negative) to 6 (very high/positive).

Table 3 shows the pre-post changes in student responses. In the pre-test, 175 instances were found where student responses differed from the engineering experts, out of a total of 186 possible instances of difference (96%). In the post-test, 174 instances of difference were found of a total of 186 possible instances of difference (again, 94%). The instances of disagreement with the experts dropped by only one instance, an imperceptible improvement. Students performed at almost exactly the same level before and after exposure to engineering and technology integration. It is not clear why there was so little change between the pre- and post-test.

Table 3

College	Process (N=19)		Context (N=5)		Products (N=7)	
	Pre-	**Post-**	**Pre-**	**Post-**	**Pre-**	**Post-**
Berkshire CC	16	15	5	5	7	7
Fitchburg State	18	18	5	5	7	7
MCLA	17	17	5	5	7	7
Massasoit CC	17	17	5	5	7	7
Middlesex CC	18	18	5	5	7	7
Salem State University	17	17	5	5	7	7
Total	103/114	102/114	30/30	30/30	42/42	42/42

In the added section on attitudinal changes, eleven statements asked participants were to retrospectively rate their thinking both BEFORE and AFTER participation in the course. All eleven statements showed significant improvement, with only small changes in the standard deviation. Table 4 shows participant responses for the attitudinal section.

Table 4

Item	Mean: BEFORE	Mean: AFTER
I like to learn about engineering	2.98	4.33
I like to think about engineering	2.66	3.88
I notice engineering in the news	2.64	3.85
I like to talk about engineering	2.14	3.14
I feel like I can learn about engineering	3.23	4.50
I feel like I can be good at engineering	2.56	3.68
I feel like I will benefit from learning more about engineering	3.12	4.52
I admire people who are in engineering	3.77	4.88
I think about pursuing further study in engineering	2.00	2.65
I think about how engineering will fit into my career	2.13	3.18
I pay attention to the place of engineering in society	2.42	3.94
Attitudes toward Engineering (max=66)	**29.70**	**42.62**

The final section of the survey was for preservice teachers only, so the sampling frame is smaller (N=99). The seven statements were intended to gather information on the respondents' attitudes toward the place of engineering in their future teaching. Participants were asked to retrospectively rate their agreement with the statements both BEFORE and AFTER participation in the course. Table 5 summarizes the findings for this section. All seven statements showed significant positive change although the gains for both groups were normally distributed (meaning that some respondents reported greater gains than did others).

Table 5

Item	Mean: BEFORE	Mean: AFTER
I feel like I can help children to learn about engineering	2.45	3.98
I feel like I can guide children through a class engineering project	2.51	4.05
I think my students will have a good awareness of engineers	2.51	3.91
I think my students will have little knowledge of engineering	2.95	3.50
I think my students will not be able to learn the vocabulary they will need to do class engineering projects	2.72	3.72
I think my students will enjoy doing class engineering projects	3.14	4.59
I think my students will learn a lot from doing class engineering projects	3.30	4.69
Attitudes toward Teaching Engineering (max=42)	**19.76**	**28.53**

<u>June 2011-May 2012</u>

Faculty Professional Development

The 3-day workshop held for BEST faculty in June 2011 was evaluated via an online survey administered at the conclusion of the workshop. Faculty participants answered questions that explored their attitudes around engineering and technology: towards the content, self-efficacy around teaching the content, and anticipated student responses to content, as well as a few open-ended questions which asked how participation in the BEST project had contributed to their improvement as a teacher and what lingering obstacles made engineering integration difficult.

In the 16 questions that asked faculty to retrospectively rate changes in their attitudes towards engineering, their own skills at teaching engineering, and their expectations for student learning both BEFORE and AFTER participating in the 3-day workshop, all items showed significant pre-post change, although gains were normally distributed (meaning some people gained more and others gained less). Overall, participants moved from 59% of the maximum to 87%. This strong increase in attitudinal response shows the value of the June professional development for faculty's continued commitment to integrating engineering and technology into their courses. When asked to identify the largest barrier to implementing engineering integration in their courses, faculty again reported that the crowded curriculum was the biggest hurdle.

The open-ended responses regarding faculty's growth as a teacher due to participation in the grant, the responses tended to fall into two categories: personal growth and professional growth. The following are examples of faculty responses:

- [personal growth] *To my surprise, I have found that I have a natural aptitude for engineering. My father and brothers all have this, but I thought it had passed me by. Recognizing my own capacity for engineering gives me the confidence to teach it.*
- [personal growth] *I feel energized! The networking and exposure to new ideas has energized me to develop new materials for teaching.*
- [professional growth] *I have found an exciting way to help non-majors [in science] understand how engineering and technology is involved in their everyday lives and how closely related it is to the other sciences especially biology.*
- [professional growth] *I gained wonderful ideas about incorporating the simplified engineering design process into activities for lab.*

Faculty Focus Group

During summer 2012, DSRA conducted two 40-minute focus group interviews. These focus groups explored how participants' ideas about engineering have evolved over the time during which they have participated in the BEST project. Six science faculty were interviewed in the first focus group and six education faculty in the second group. Faculty were asked to describe their thoughts in the following categories:

- Motivation (why are they integrating engineering into their course?)
- Processes of adoption (how do they implement engineering into their course?)
- Strength of adoption (how much of their current curriculum relates to engineering?)
- Extent of adoption (how much has engineering permeated non-engineering content?)
- Impediments to a greater adoption (what are obstacles to a wider implementation?)

The following summarizes participants' thoughts on the above categories and provides examples of responses for each category.

Motivation: Participants referenced either personal experience or shifts in educational policy as motivations for introducing engineering in their classes:

- *He scored like two points below "advanced" and so that's when I really started to put the emphasis into the engineering into my student teaching because they're going to have to know it so I might as well bring current topics and exercises for them to do to expose kids earlier in their teaching.*
- *Then the other piece is that I think not only looking at MCAST and all of those things but we—our critical thinking skills, that's another area that has been as area of deficit from pre-K all the way through higher ed that we're seeing and the problem-solving piece of it.*

Process of Adoption: Teachers appeared to cite the importance of teacher confidence in being able to facilitate the engineering lesson, and then during the lesson, the importance of evidence of student engagement was cited as important.

- *When I came to this program last year it was with some trepidation because I know engineers and I know some elementary school teachers and they are very, very different in terms of the way they think and solve problems, etc. so I wasn't sure that it was possible for elementary school teachers to teach engineering concepts to children.*
- *I think that even someone who thinks as differently as an elementary school teacher would from someone who has a degree in engineering, given that difference the elementary school teacher could use the materials with children and they would get a glimpse at this whole process.*

Strength of Adoption: Overall, the presence of engineering appeared to have penetrated about 20% of the participants' lessons. This is a change from no engineering at all over the course of the project, a remarkable gain.

- *In terms of quantity of how much engineering we're going to put in here I don't think we need to have a lot of specific units, 10, 20%. You do a unit or two so they get an idea of it but then that's not just the limit because the rest of the semester one of the goals that I have is that when we're talking about something completely different they're going to be starting to pull out engineering ideas. Because they've had this exposure to the engineering they're not going to be afraid of – we can be doing this life science lesson or lab but I want them to be thinking how could we change this, how could we redesign the technology we're using and start to incorporate it into just their sort of mindset.*

Extent of Adoption: Engineering and the engineering design process appeared to have some "ripple" effects through the then teachers' other lessons. The extent of this effect was not very clear, but it seems that the participants had, to varying extents, "internalized" the engineering mentality.

- *Like the engineering part I found different things about production engineers for all types of things. Then also they would do group projects and it was set up so that they would form groups, work in class some but then do some more things outside of class. Then I monitored them during those three to four weeks. There were progress reports that they would have to give to me and that, of course, counted for part of their grade.*

Impediments to a Greater Adoption: These impediments were generally the competing content coverage demands on the participants.

- *I have an enormous amount of material that I sort of should be covering so this fits well with a part of it and really highlights a part of it but I need to be cognizant also of what's going to be required of teachers when they get out into the field. Engineering is, I think, important but I don't think – there's math and science – math even then before science but in terms of what's going to be required of teachers when they go out in the field those are sort of – I have to be aware of what they're going to be asked to do and be held accountable for.*

Overall, DSRA concluded from the two focus groups that the participants were very enthusiastic about using engineering and that engineering is likely to be present in about 20% of the lessons taught. This is an enormous increase over a very short period of time, with lessons using engineering moving from non-existent to roughly one in five over the first two years of the BEST grant. The focus groups supported the importance of the affective dimension in the initial adoption of the engineering innovation. Teachers needed to feel reasonably confident that it can work, and co-teaching the engineering unit with an experienced colleague (which multiple faculty reported having done in order to disseminate engineering integration) helped bolster confidence. The effects of innovation are also strongly influenced by perceived levels of student engagement, with this phenomenon visible to the attentive teacher.

Impediments to a greater incorporation of engineering were cited as the already crowded curriculum, with many associated demands placed on the faculty. What the responses did not identify was what is present in the local contexts of each college that may enable or impede a larger diffusion of the innovation through the non-participating faculty.

Course Integration

Students in the Fall 2011 semester were given the survey of 31 engineering statements both before and after experiencing the integration of engineering and technology in their course. The post-test included the two additional sections which were present in the Spring 2011 survey. Students (N=360) from eight Massachusetts colleges participated in the student survey in Fall 2011. In the students' pre-test data, DSRA found 222 instances of difference from expert engineers out of a possible 248 instances (90%). At the post-test DSRA found 96 instances of difference out of a possible 186 (52%). This is an enormous gain, with the differences between the students' judgments and those of engineering experts strikingly reduced. The reduction in instances of difference in the process and product categories is noticeably larger than in the context category. This suggests that faculty tended to emphasize the engineering design process and different types of technologies more than they emphasized the larger context of engineering in society. Table 6 summarizes student responses by college and by category.

Table 6

	Process (N=19)		Context (N=5)		Products (N=7)	
College	**Pre-**	**Post-**	**Pre-**	**Post-**	**Pre-**	**Post-**
Fitchburg	18	8	5	3	7	2
Massasoit	18	-	5	-	7	-
Middlesex CC	17	5	4	3	7	1
Salem State	12	14	1	5	7	5
Berkshire	16	-	5	-	7	-
North Shore CC	17	17	5	5	7	6
Bristol CC	16	2	5	2	7	4
Bridgewater	18	9	4	3	7	2
Total	132/152	55/114	34/40	21/30	56/56	20/42
% of Items Showing Significant Difference	**87%**	**48%**	**85%**	**70%**	**100%**	**48%**

The next section of the post-test included the eleven statements which were intended to gather information on changes in respondents' attitudes toward engineering. All eleven statements showed significant improvement, with small changes in the standard deviation. The overall pre-post change was also significant, although the gains were found to be normally distributed (meaning that some students gained more and others less). Data is summarized in Table 7.

The last section of the post-test was for preservice teachers only, so the sampling frame is smaller (N=105). These seven statements were intended to gather information on the respondents' attitudes toward the place in engineering in the respondents' future teaching. Each statement was found to show significant positive change, and the overall change between BEFORE and AFTER also showed significant improvement. The gains for both groups were normally distributed (meaning that some respondents reported greater gains than did others). Table 8 summarizes the data for this section.

Table 7

Item	Mean: BEFORE	Mean: AFTER
I like to learn about engineering	3.04	4.40
I like to think about engineering	2.78	3.96
I notice engineering in the news	2.88	3.92
I like to talk about engineering	2.36	3.46
I feel like I can learn about engineering	3.39	4.56
I feel like I can be good at engineering	2.57	3.75
I feel like I will benefit from learning more about engineering	3.22	4.48
I admire people who are in engineering	3.92	4.85
I think about pursuing further study in engineering	1.64	2.34
I think about how engineering will fit into my career	2.19	3.51
I pay attention to the place of engineering in society	2.52	3.91
Attitudes toward Engineering (max=66)	34.40	48.45

Table 8

Item	Mean: BEFORE	Mean: AFTER
I feel like I can help children to learn about engineering	2.10	3.88
I feel like I can guide children through a class engineering project	2.32	4.01
I think my students will have a good awareness of engineers	2.37	3.77
I think my students will have little knowledge of engineering	2.72	3.19
I think my students will not be able to learn the vocabulary they will need to do class engineering projects	2.50	3.15
I think my students will enjoy doing class engineering projects	3.11	4.44
I think my students will learn a lot from doing class engineering projects	3.35	4.60
Attitudes toward Teaching Engineering (max=42)	18.48	27.31

June 2012-May 2013

Faculty Professional Development

The 2-day workshop held for BEST faculty in June 2012 was evaluated via an online survey administered at the conclusion of the workshop. Faculty participants answered questions that addressed the helpfulness of specific components of the workshop. These questions explored (1) the effects of the different activities on respondents' ideas and interests, (2) the value of the various activities, and (3) how likely participants would be to attend a similar workshop and whether they would recommend the experience to colleagues. All scaled items used a six-point scale (with 1 being very low to 6 being very high).

When participants were asked to rank five possible benefits of participating in the workshop in a forced ranking, the two benefits that were reported as most helpful were: 'the opportunity to meet with other faculty' (mean: 3.67, mode: 5) and 'the increase in my awareness of how what I do might be able to contribute to expanding the place of engineering in education' (mean: 3.67, mode: 3). The two workshop activities that participants identified as most helpful was time dedicated for faculty to collaboratively 'plan for expanding engineering course integration and engineering activities for preservice education students' (mean: 5.53, std dev: 1.55) and time dedicated to a student panel (mean: 5.40, std dev 1.60). In the collaborative planning time, faculty grouped together first by course subject area and then by college. During the student panel, students from four participating BEST colleges spoke about their experiences in courses integrated with engineering and technology, as well as how this integrated coursework contributed to their practicum experiences.

Respondents reported that they would be very inclined to attend another similar workshop (mean: 5.87, std dev: 0.52) and 80% said they would definitely return. DSRA concluded that the workshop was successful in facilitating the growth in ideas and interest in using engineering among attendees. The workshop included a wide array in the seven activities over the two days, and the participants expressed strong degrees of consensus around the high value of all activities. Participants reported that the workshop was well worth the expenditures of time and effort, and expressed that they left feeling renewed and re-committed to the importance of engineering in their work.

What is next for BEST?

As the BEST grant winds down, grant staff are focused primarily on continuing to improve evaluation methods, and further dissemination of the BEST models for integration.
While evaluations have shown the BEST grant is effective in improving faculty and student attitudes toward engineering, questions about the implementation strategies used by the faculty remain. To better understand this facet of the program, grant staff, with the feedback of BEST faculty, have developed a new student survey designed to determine whether faculty and staff are successfully imparting the engineering and technology learning objectives that they have identified as most important. Data will help faculty identify which of their engineering activities have the highest efficacy. During the June 2012 workshop, faculty identified a number of learning objectives which they felt (a) students might not be learning and (b) ones that students often formed misconceptions around. The new student survey addresses these learning objectives in a manner that is intended to help faculty connect the types of engineering activities they use in their course with the specific learning objectives that students leave their course with, as well as the depth of their new understanding of engineering and technology topics.

The other area where grant staff hope to more fully develop BEST is in its dissemination of engineering and technology to other non-participating faculty and even non-participating colleges. In order to achieve this, grant staff and BEST faculty have collaborated to develop a standard template for faculty to use when describing engineering modules. These templates are intended to help faculty who are new to this kind of integration to understand and adopt relevant models. As faculty submit these templates, grant staff are organizing them into what will eventually grow into an online searchable database. Another strategy for implementation that is ongoing is the development of a series of course videos that show BEST faculty in their classrooms working with real students and demonstrating the different engineering activities that they use in their course modules.

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