Research and Evaluation for the Engineering is Elementary Project, 2004–2016

An Executive Summary

EiE Engineering is Elementary®

Developed by the Museum of Science, Boston

Engineering is Elementary (EiE) is a research-based program that has incorporated research, evaluation, and assessment into all aspects of curriculum design and testing from its inception. Our research questions, assessment instruments, and methods continue to evolve as the project grows and matures. This document summarizes some of the most notable findings from the project's first ten years as reported by studies conducted by project staff and external evaluators. The findings from most of these initial studies merit larger-scale, follow-up studies to examine them in more detail. The cited full reports and papers can be found on our website: http://www.eie.org/engineering-elementary/eie-research

Conceptions of Engineering

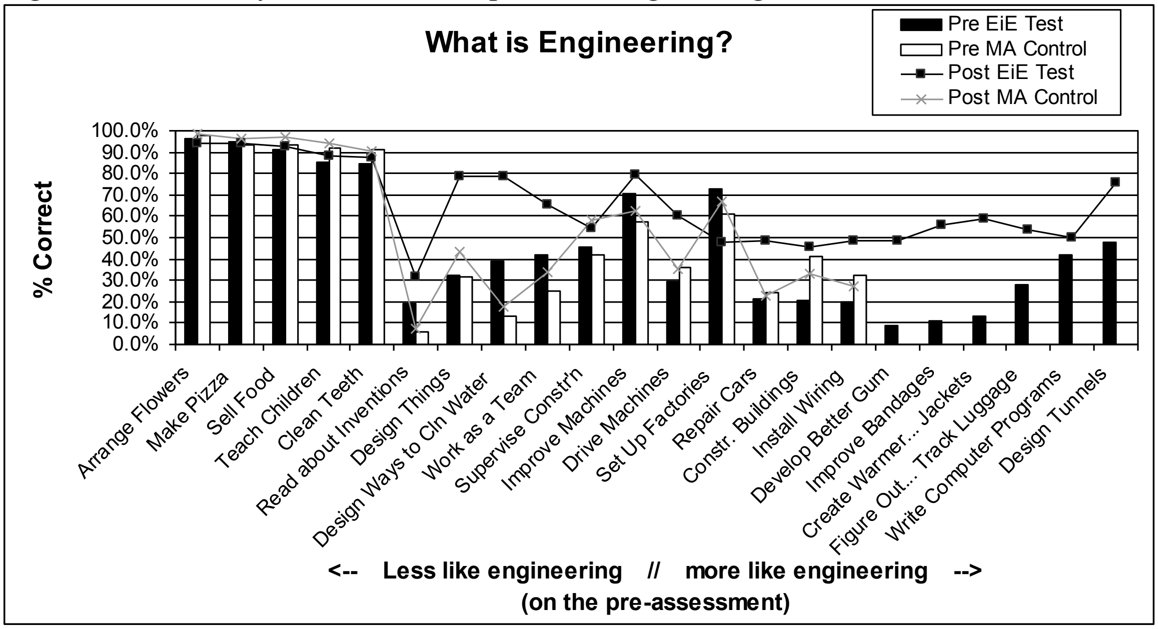
Student Conceptions:

An instrument—the Draw an Engineer Test—probed children's conceptions of engineering, asking them what engineering was, to draw an engineer at work, and to describe their picture in words. The results suggest that students have limited understandings of the type of work engineers do. Drawings focus heavily on constructing roads, buildings, or bridges; fixing cars; using or fixing computers; and driving trains. An awareness of the range of fields that engineering encompasses is fairly limited and student responses focus heavily on structures (construction workers: civil engineering), cars/machinery (auto mechanic: mechanical), and computers (computer technician: computer/electrical engineering) (Knight & Cunningham, 2004).

To more systematically probe children's conceptions of engineering the EiE team developed the "What is Engineering?" instrument that included captioned images of people working and asked students to choose those items that an engineer would do at work. Students were also asked to respond to the open-ended question "What is an engineer?" Over 7000 students completed a pre- and post- test of the validated instrument. Findings reveal similar patterns between students from all regions and ethnic groups—students tend to focus on the descriptor noun and not the verb: they are most likely to choose jobs involving construction or machines as engineering, such as "install wiring," "construct buildings," or "repair cars" and least likely to identify engineering that focused on non-mechanical/civil fields such as environmental "design ways to clean water," chemical "develop better bubble gum," and industrial "figure out ways to track luggage" (Christine M. Cunningham, Lachapelle, & Lindgren-Streicher, 2005).

In a first comparison with a control sample drawn from Massachusetts students, we have found through pre- and post-assessments that students participating in EiE units show dramatic and significant change in their understanding of the kinds of work that engineers do compared to children who do not use the EiE materials. Post-test of EiE students indicate they are significantly more likely to identify engineering items relating to the design of all types of technology, and they are less likely to choose non-design items relating to construction or repair work (see Figure 1) (Christine M. Cunningham et al., 2005; Lachapelle & Cunningham, 2007).

Figure 1: Elementary Students' Conceptions of Engineering



Further refinement of the "What is Engineering?" instrument has been implemented, including addition of questions about what types of activities are important to the work of engineers, construction of scales based on the conceptions of engineering that have been observed in previous studies, and validation of the instrument. Over 1000 Minnesota students in third and fourth grade who had not yet started EiE were assessed using the most recent version of the instrument, then compared with a sample of professional engineers. Based on the results, use of the "What is Engineering?" instrument confirms that students' naïve conceptions of engineering focus on working with electronics, repairing or installing things related to cars, and constructing large building projects using tools, and not tasks like non-electronic design (as in "develop better bubble gum"). Once again, students are focusing on the subject of the work, not the type of work being done. In comparison, professional engineers have very clear ideas about what is and is not engineering based on whether or not the work involves designing and inventing, not what it is that is being designed (Lachapelle, Phadnis, Hertel, & Cunningham, 2012).

More recently, 731 Minnesota third, fourth, and fifth grade students completed the instrument prior to and after experiencing an EiE unit. For most demographic groups, these students' scores on the whole instrument increased significantly from pre- to post-tests (Lachapelle, Hertel, Shams, & Cunningham, 2013). We are currently using Structural Equation Modeling analysis to further refine the "What is Engineering?" instrument and explore students' conceptions of engineering before and after engaging in engineering education.

Teacher Conceptions:

The "What is Engineering?" instrument was also administered to 100 teachers. Teachers' responses followed a pattern similar to students, although they were more likely on all items to correctly discriminate between engineering types of work and non-engineering work (C. M. Cunningham & Lachapelle, 2007).

Conceptions of Technology

Student Conceptions:

A “What is Technology?” instrument that asked children to choose which captioned items were technology was also developed by the EiE team and administered to nearly 7,000 grade 2-5 students across the country. In general, children identify technology with items that run on electricity and power (Christine M. Cunningham et al., 2005; Lachapelle & Cunningham, 2007) and are unlikely to view items such as bandages, cups, or shoes as technology. These results are robust when compared by region or gender, though males are slightly more likely than females to have a broader conception of technology (Lachapelle & Cunningham, 2007).

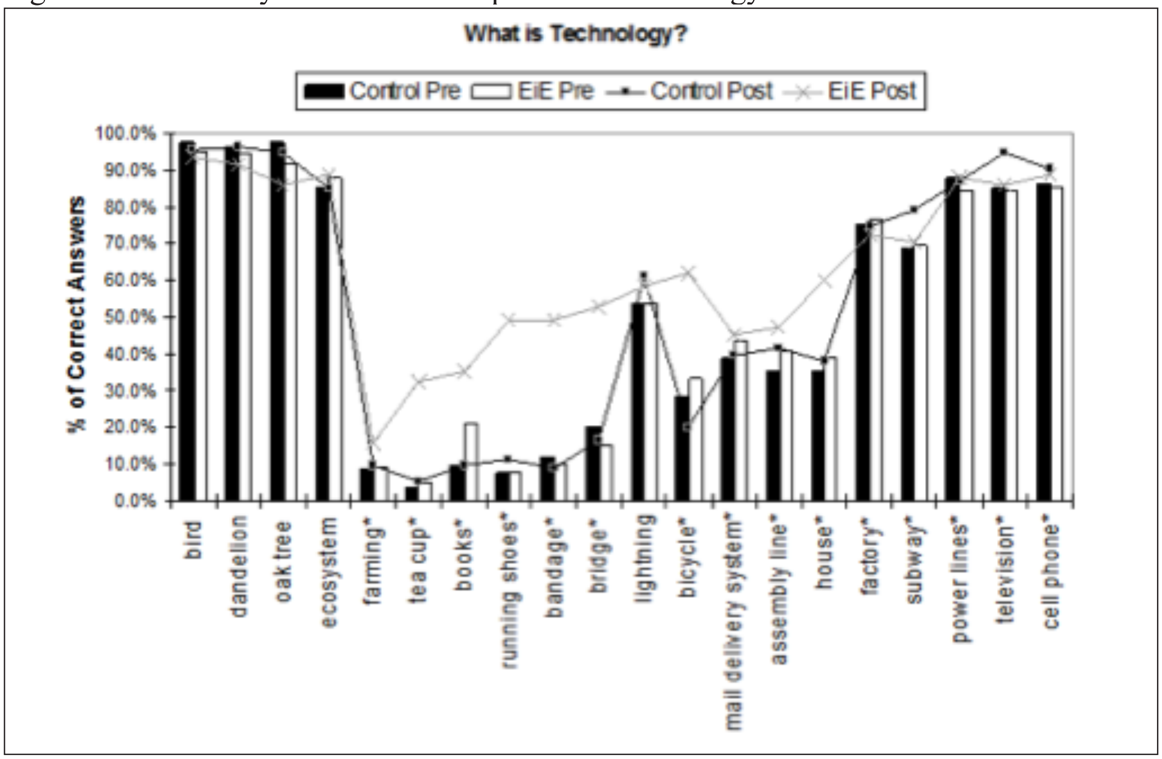
Pre- and post-assessments of a national sample of students engaged with EiE materials when compared with a control group in Massachusetts that did not use EiE demonstrate that the EiE curriculum has a dramatic, significant impact on broadening students’ understanding of technology. After completing an EiE unit, students are significantly more likely to indicate that common-place, human-made items are technology (Lachapelle & Cunningham, 2007).

A more recent analysis of a newer version of the “What is Technology?” instrument looked at data collected from 2006-2009 from 1,092 students in grades 3-6. This sample included both EiE and control classrooms (57% and 43% of the sample, respectively) from multiple states including Colorado, California, Minnesota, and Massachusetts. Using the backward step-wise method of regression, a significant model emerged ($p<.001$), explaining 41% of the variance and showing a large Cohen’s d effect size (0.804) of the treatment on the post-assessment, after taking into account pre-assessment scores. Though demographic variables also affected scores, these effects were consistent across both control and treatment groups. Student choices on the post-assessment were examined using Principal Components Analysis, and were found to cluster into four components explaining 51% of the variance: Simple Technologies, Energy Technologies, System Technologies, and Non-Technologies. Students engaged in EiE were more likely than the control group to choose Simple Technologies and System Technologies as technologies (Jocz & Lachapelle, 2012). Students’ responses to individual items are shown in Figure 2.

The most recent version of the “What is Technology?” instrument has been used by groups of 242 students (Lachapelle, Jocz, & Phadnis, 2011), 508 students (Lachapelle, Hertel, Phadnis, & Cunningham, 2013) and 788 students (Lachapelle, Hertel, Shams, et al., 2013), all from Minnesota,before and after engaging in EiE units. For all groups, scores increased significantly from pre- to post-test; when a control group was used, EiE students improved significantly more than control students. These data reinforced that students even before participating in EiE can correctly categorize non-technologies and electronic technologies, but have a tendency to incorrectly identify non-electronic technologies. This tendency does not appear as strongly on post-tests, suggesting that students gain a more accurate and nuanced understanding of technology following participation in EiE.

We are currently analyzing data from another large sample of students who completed the "What is Technology?" instrument by using Structural Equation Modeling. Through this, we hope to gain a clearer picture of the pieces of students' conceptions and misconceptions about the nature of technology, as well as confirmation of the value of the instrument.

Figure 2: Elementary Students' Conceptions of Technology



Teacher Conceptions:

Teachers show a similar pattern of responses though their conception of technology is much more likely to be congruent with the definitions of technology as any thing or process that humans have created to meet human needs or desires (C. M. Cunningham & Lachapelle, 2007; Christine M. Cunningham, Lachapelle, & Keenan, 2010).

Impact of EiE on Students

Impact of EiE on Student Understanding of Engineering and Science Concepts

During the development, pilot testing, and field testing of each EiE unit, students in grades 2-5 engaged in that unit complete a pre- and post-assessment.

Questions measure (a) general engineering and technology concepts, (b) concepts specific to the engineering field of focus in that unit, (c) engineering and technology concepts that are taught in the unit, and (d) understanding of the relevant science concepts that are reinforced by engineering activities.

The first round of analysis of student results from the pre- post-assessments of the first six EiE units found that, on more than 75% of questions, EiE students performed significantly better on the post-assessment than on the pre-assessment. In most cases where a control sample was available for comparison, EiE students performed significantly better than the control. This was true for both genders and all racial/ethnic groups (Lachapelle, 2007). An analysis of improvements made by students of teachers participating in the Pre-College Engineering for Teachers (PCET) professional development project found similar results (Lachapelle, Cunningham, Oware, & Battu, 2008). After completing an EiE unit, students demonstrated:

A better understanding of the specific kind of tasks that engineers working in a specific field (e.g., environmental engineers) might do for their job

- A better understanding that engineering involves design and teamwork.
- A better grasp of relevant engineering and technology vocabulary.
- A better understanding of the engineering design process.
- A better understanding of materials, their properties, and their uses in engineering design scenarios.
- An increased likelihood of understanding science content related to the unit.
- A better understanding of how to improve technologies.
- A better understanding of what a process is and how it is a type of technology.
- A better understanding of the criteria for judging the effectiveness of a technology (Lachapelle, 2007; Lachapelle et al., 2008).

A second round of analysis of units 7 through 15 compared EiE student performance against control groups, using HLM methodologies for 7 of the 9 unit analysis (the other 2 units had insufficient sample sizes for HLM analysis). Modeling again found that EiE students:

- Improved significantly on assessments,
- Performed significantly better on post-assessments than control groups when pre-assessment performance was taken into account,
- Performed significantly better than control on science questions, where a subgroup of science questions was available for analysis.

Details of findings can be found in Table 1 (Lachapelle, Cunningham, Jocz, Kay, et al., 2011).

Table 1: Effect Sizes for Classroom Participation in EiE Field Test Units 7-15

Unit	Outcome	Treatment Effect Size	Pre Class Mean Effect Size	Topics Assessed
7: Designing Alarm Circuits	PostAll	0.372	0.257	interpret schematic diagrams of circuits; identify aspects of electrical engineering; & science topics (below)
	PostScience	0.470	0.273	electrical current; insulators; conductors; forms of energy
9: Seeing Animal Sounds	PostAll	0.420	0.301	how to change sounds; how to represent sounds; how different materials affect sound; aspects of acoustical engineering; & science topics (below)
	PostScience	0.311	*	properties of sound: pitch, volume, duration
10: Evaluating a Landscape	PostAll	1.367	0.272	geotechnical engineering; foundation design; models; erosion
	PostScience	1.070	0.356	erosion
11: Designing Maglev Systems	PostAll	2.339	0.408	aspects of transportation engineering; design of maglev transportation systems; properties of magnets
13: Designing Plant Packages	PostAll	0.324	0.272 By treatment: 0.218	Packages; package engineering; needs of plants; functions of plant structures
14: Designing Solar Ovens	PostAll	0.689	0.570	green engineering; how solar ovens work; heat energy; insulation
15: Designing Parachutes	PostAll	1.292	0.551	design and operation of parachutes; aerospace engineering; & science topics (below)
	PostScience	1.045	0.456	atmospheric properties; the effects of drag on falling objects

***Variable tested but not significant.**

A third round of analysis of units 16 through 20 compared EiE student performance on post-assessments against the pre-assessment, using t-tests and confidence intervals—a control group was not available. Analysis found that EiE students participating in all 5 units:

- Improved significantly on engineering questions ($p<0.001$, all scales)
- Improved significantly on science questions ($p<0.001$, all scales)

Details of findings can be found in Table 2 (Lachapelle, Cunningham, Jocz, Phadnis, et al., 2011).

Effect sizes found for participation in EiE units 7-15 ranged from small to large across units; however, effect sizes are likely to be somewhat inflated for "PostAll" scores, which included engineering questions, since the control group did not receive engineering instruction. Similarly, significance of changes pre- to post- on engineering questions for students participating in EiE units 1-6 and 16-20 are likely to be inflated. For this reason, and also because the data was collected from convenience samples (not randomized samples) of field test and control classrooms, or not compared to control samples, these findings are promising but not conclusive (Lachapelle, 2007; Lachapelle, Cunningham, Jocz, Kay, et al., 2011).

Table 2: Reference Group Change in Score for EiE Field Test Units 16-20

Unit	Topic Assessed	Change in Score (Reference Gp)	95% CIs	t	df	p-value
16: Cleaning Up an Oil Spill (CO)	Environmental Engineering	1.65	[1.47, 1.82]	18.711	57	<0.001
	Science (Food Webs)	2.00	[1.74, 2.27]	15.052	57	<0.001
	Pollution	1.15	[1.01, 1.30]	16.062	58	<0.001
17: Replicating an Artifact (RA)	Properties of Materials	1.20	[1.01, 1.39]	12.565	60	<0.001
	Rocks	2.84	[2.60, 3.08]	23.598	61	<0.001
18: Designing Submersibles (SB)	Ocean Engineering	1.86	[1.57, 2.15]	12.876	36	<0.001
	Science (Sinking & Floating)	1.27	[1.01, 1.53]	9.880	37	<0.001
19: Designing Knee Braces (KB)	All	3.46	[3.20, 3.72]	26.864	604	<0.001
	Biomedical Engineering	1.50	[1.40, 1.59]	31.862	605	<0.001
	Models	1.09	[0.97, 1.22]	17.797	604	<0.001
	Science (Bones & Muscles)	0.95	[0.81, 1.08]	13.983	604	<0.001
20: Designing Lighting Systems (LS)	Optical Engineering	0.76	[0.56, 0.96]	7.527	55	<0.001
	Engineering Design	0.38	[0.29, 0.47]	8.556	55	<0.001
	Properties of Light	0.59	[0.47, 0.71]	9.540	56	<0.001
	Brightness & Movement of Light	0.91	[0.73, 1.10]	10.060	53	<0.001

Data from the use of EiE in Minneapolis and Hopkins, Minnesota, from 2009-2013 provide further evidence for the potential positive effects of the curriculum on student learning in science and engineering (Lachapelle, Jocz, & Phadnis, 2011; Lachapelle, Hertel, Phadnis, et al., 2013; Lachapelle, Hertel, Shams, et al., 2013). Student responses on content-specific instruments before and after participating in an EiE unit (including Designing Maglev Systems, Designing Water Filters, Designing Model Membranes, Seeing Animal Sounds, Cleaning an Oil Spill, and Making Work Easier) in many cases showed significant improvement in science and engineering scores from pre- to post-test. This study, as with the earlier pilot testing, should be considered promising but not conclusive, as most analyses did not feature control data.

Impact of EiE on Students' Interest in and Attitudes towards Science and Engineering Careers

Students who completed the Engineering is Elementary curriculum were significantly more likely to report interest in being an engineer on the post-survey than control students. They were also significantly more likely than control students to report interest in and comfort with engineering jobs and skills, and to agree that scientists and engineers help to make people's lives better (Christine M. Cunningham & Lachapelle, 2010). This improved interest in engineering has been confirmed by a later study, which also found that student demographics have minimal effect on this interest (Lachapelle, Phadnis, Jocz, & Cunningham, 2012).

The responses of boys and girls changed similarly in direction and size from the pre-survey to the post-survey, but girls' and boys' responses overall were significantly different on all questions regarding engineering jobs. Boys showed more interest than girls in the questions having to do with inventing, figuring things out, cars, and structures; girls showed more interest in the jobs to do with helping society and people. In addition, both boys and girls were significantly more likely to agree that they would enjoy being an engineer after completing an EiE unit, but boys reported more interested than girls on both the pre- and post-survey (Christine M. Cunningham & Lachapelle, 2010). The gender differences between inventing and helping, as well as EiE's effect on interest in engineering careers, have been confirmed by a later study. This same study showed that while the increases in reported enjoyment of being an engineer were significant for both boys and girls, the positive effect of EiE on girls' reported interest was significantly more than for boys (Lachapelle, Phadnis, Jocz, et al., 2012).

These potential effects of EiE on student attitudes about engineering careers are reinforced by data collected in Minnesota during 2009-2010 (Lachapelle, Jocz, et al., 2011). The 2010-2011 school year of data from these same sites also provided evidence for these effects. Changes from pre-EiE to post-EiE surveys showed students responding significantly more positively after EiE to statements about science and engineering, specifically as professions that help people and as enjoyable future careers (Lachapelle, Hertel, Phadnis, et al., 2013).

Impact on Underrepresented / Underserved Students

Teachers participating in the Pre-College Engineering for Teachers (PCET) professional development project reported that EiE works well with all students, whether low- or high-achieving, including students: with cognitive challenges, linguistic challenges, behavioral challenges, who are gifted and talented, who are girls, who are children of color, and who are at-risk in other ways. Of all these populations teachers agreed most strongly that the curriculum worked with children of color (Faux, 2008).

A small study of teachers' perceptions of the impact of EiE on students from groups historically underrepresented in STEM fields (females, low-income, historically underrepresented minorities, IEP, English Language Learners), found that the majority of the 46 teachers responding to the survey indicated that student engagement, as well as their performance, in EiE was higher than it was in science. For some but not all groups, most teachers indicated that engagement in EiE was also higher than it was in school in general. Between 30 and 52 percent of teachers (percentages varied depending upon the sub-group) also indicated that performance in EiE was higher than it was in school in general. Most teachers also reported that using EiE had a positive impact on student interest in science, engineering, and mathematics, as well as student engagement and performance in school (Weis & Banilower, 2010).

A large-scale study of field test versions of EiE units 7-15 provides further evidence that EiE works well for all students. In most cases, demographic variables including whether a student has limited English proficiency (LEP), received free or reduced-price lunch (FRL), has an Individualized Education Program (IEP), or is from an underrepresented minority group (Is_Black or Is_Hispanic) were associated with poorer performance on both pre- and post-assessments, but this relationship was not moderated by treatment: the difference was the same for both the control and test groups (Lachapelle, Cunningham, Jocz, Kay, et al., 2011). A later study (Lachapelle, Phadnis, Jocz, et al., 2012), has returned similar results: student demographics rarely affected interest in and attitudes about engineering and related fields. Regardless of demographics, students who engaged with EiE were more likely to report that they "know what engineers do for their jobs" following participation (Lachapelle, Phadnis, Jocz, et al., 2012). While girls and boys, regardless of their participation in EiE, were showed interest in different types of engineering activities, (girls preferring helping people and the environment, and boys preferring inventing and figuring things out), both girls and boys were more likely to report that they "would enjoy being and engineer when [they] grow up"; the effect that EiE had on girls for this attitude towards engineering careers was even more pronounced than for boys (Lachapelle, Phadnis, Jocz, et al., 2012).

Teachers' Perception of the EiE Curriculum

Teachers who use EiE in their classrooms rate the EiE curricular materials highly (Carson & Campbell, 2007a, 2007b; Faux, 2007; Lachapelle, Cunningham, Jocz, Kay, et al., 2011). Teachers participating in the Pre-College Engineering for Teachers (PCET) professional development project strongly and significantly agreed that EiE units are well designed, that the EiE units they used fit into the required curriculum, rather than being 'one more thing' to teach, and that EiE units are well matched to the level of students (Faux, 2007). Teachers participating in field testing of EiE units 7 through 20 similarly agreed that EiE units furthered their objectives for science and engineering, positively affected their students' motivation, and are age-appropriate (Lachapelle, Cunningham, Jocz, Kay, et al., 2011; Lachapelle, Cunningham, Jocz, Phadnis, et al., 2011). The same reports found that teachers consistently rated highly EiE's reinforcement of science learning objectives, and also cited other connections to literacy, math, and social studies as valuable in free response.

After using the EiE materials with their students, PCET teachers and field test teachers highly rate aspects of EiE indicating that they would do the unit again with their class, and that they found the directions clear and felt comfortable leading the lessons (Carson & Campbell, 2007a; Lachapelle, Cunningham, Jocz, Kay, et al., 2011). PCET teachers additionally agreed that the science and literacy connections were useful, and that overall they found that the materials for the activities were easy to get and students were able to successfully complete the design challenge (Carson & Campbell, 2007a).

Teachers see the EiE materials as an excellent fit for elementary school students and teachers, most often citing as strengths: the hands-on approach used by the units, the sound pedagogical design of the units, the ease with which they can be adapted to fit local circumstances, the collaborative nature of the activities, and the many ways in which using the units promotes a greater awareness of the ubiquity of engineering in the lives of the students. Concerns about the units, when voiced, focused on the length of time required to do the lessons, the acquisition and management of material resources to support the lessons, and the reading level of the EiE stories (Faux, 2006; Lachapelle, Cunningham, Jocz, Kay, et al., 2011; Lachapelle, Cunningham, Jocz, Phadnis, et al., 2011).

When asked to compare their experiences teaching EiE and traditional elementary science curricula, PCET teachers strongly agreed that with EiE, students: learn science concepts better, are more engaged, are more collaborative, are more creative, and make real world science/engineering connections (Faux, 2008). Similarly, many EiE field test teachers indicated, when asked "How did your students benefit, academically or otherwise, from taking part in this unit?" that EiE units provide opportunities for students to learn more about science and engineering, and their students learned unit-specific science and engineering content (Lachapelle, Cunningham, Jocz, Kay, et al., 2011; Lachapelle, Cunningham, Jocz, Phadnis, et al., 2011). In the same reports, many teachers also mentioned that their students gained a deeper understanding of the work of an engineer and were better able to recognize engineering in everyday life. A number of field test teachers also described how their students' problem solving, critical thinking, teamwork, and communication skills were improved. Another common response was that students enjoyed the unit and were engaged, especially with hands-on activities.

Impacts of EiE Professional Development and EiE Implementation on Teachers

EiE is very interested in the effect of professional development and implementation of an EiE unit on teachers and their pedagogies. In general, EiE staff conduct a workshop evaluation at each program we offer—most of our data to date come from teachers who have both attended professional development and implemented a unit in the classroom and we have not yet teased apart the relative influence of these two experiences on teachers' responses.

However, because EiE was initially funded as a curriculum development program that was not supposed to require professional development for implementation, one evaluation study did examine whether both trained and untrained teachers could use the materials effectively. It revealed that teachers found it easy to implement the EiE curricular materials, even without training. Both types of teachers indicated that they were comfortable doing the units, felt their knowledge after reading the unit guide was adequate to do the units, and believed that their students were successful in completing the design challenges (Carson & Campbell, 2007b).

Teachers are Satisfied with Professional Development Programs

EiE staff have offered hundreds of professional development programs to thousands of teachers and have also trained hundreds of teacher educators who do EiE professional development in diverse localities across the country. Professional development may range from a program that is two hours to one that is more than two weeks in length.

Teachers consistently express a high degree of satisfaction with EiE professional development services. They strongly agree that workshops are well planned and structured, that they are learning by doing, and that the EiE units and materials are presented in a manner that helps them feel comfortable using them in their classroom. The workshops, they feel, prepare them to do an engineering project in their classroom (Faux, 2007).

Teacher Gains in Knowledge of Engineering and Technology

Teachers also report large gains in their engineering knowledge and understanding as a result of participating in professional development programs and using EiE. They indicate significant increases in their knowledge and understanding of the range of engineering disciplines, what engineers do, and the pervasiveness of engineering in our society. Teachers report they are more knowledgeable about how engineering is practiced as well: they understand that there is not necessarily one "right" answer for engineering problems, they know about the engineering design process, they know more about the types of constraints that influence the design and selection of engineering criteria, and they are more confident in their ability to analyze the engineering solutions that their students might generate (Faux, 2007). Their understanding of engineering changes as well; after participating in EiE, the number of teachers including design, problem solving, and process/design process as part of their definitions of engineering increased dramatically (Carson & Campbell, 2007a).

Teachers' open-ended responses about engineering and technology were closer to standards-based definitions on a post-survey than on a pre-survey, after participating in EiE professional development workshops and teaching at least one EiE unit. Before participating in EiE, teachers were more likely to define technology in terms of examples, particularly tools, machines, computers and electronics, and less likely to define technology as a solution to a problem, or something designed or invented. Also before participating in EiE, teachers were slightly more likely to identify engineering as building or constructing, and less likely to define it as problem solving, a process in itself, having to do with improving things and processes, and having to do with math and / or science. Teachers also reported making greater use of engineering concepts and examples, including the engineering design process, across STEM subjects after participating in EiE (Christine M. Cunningham et al., 2010).

Teachers Report Changes in Their Pedagogy as a Result of EiE

Teachers report changes in their pedagogy after learning about EiE and teaching it in their classrooms. Interestingly, teachers report changes in their engineering teaching, their science and math teaching, and their pedagogical strategies more generally. Such changes, particularly across such a wide range of fields, are rare in education and professional development.

After participating in EiE, teachers significantly increase their use of engineering in their teaching in both science and other content areas. Particularly large increases were found in the frequency with which teachers describe engineering careers to their students, use engineering examples in science lessons, and, most impressively, use an engineering design process in their science classes. They also discuss the courses and skills needed to enter engineering. Teachers are also significantly more apt to use an engineering design process in other areas—in math lessons and science lesson as well as content areas outside of math and science (Faux, 2008).

For years, educators have been trying to help teachers develop children's problem-solving capacity. EiE seems to offer one successful possibility. External evaluations (Carson & Campbell, 2007a; Faux, 2007) have found that teachers report changes in their pedagogical strategies. After participating in EiE, teachers significantly increase their use of problem-solving strategies not explicitly related to engineering in their teaching. After using EiE, teachers evince improved attitudes toward problem-solving strategies and use more inductive methods (Faux, 2006, 2008). They also significantly increase their use of four other problem-solving strategies. They were more likely to have students: ask what they know related to the topic being studied, use things from every-day life in solving problems, work on problems for which there is no immediately obvious method of solution, and explain how they solve complex problems (Faux, 2008).

Teachers report significant changes in their use of engineering examples and the engineering design process in science, math, and other content areas. They increase the time they spend on complex and open-ended problems with their students, and increase the amount of explanation of solutions they require of their students. Over the course of implementation the reasons teachers offer for wanting to do more engineering in the classes changes from not only introducing engineering to their students to also including more of a focus on problem-solving and on incorporating more real life topics.

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

Out of School Time Curricula

We use data collected from EiE's out-of-school-time (OST) curricula primarily for formative evaluation. During pilot testing of the Engineering Adventures (EA) units (designed for 3rd-5th graders) and the Engineering Everywhere (EE) units (designed for 6th-8th graders), educators complete extensive feedback forms and administer a modified version of the Engineering Attitudes instrument to children participating in their afterschool or camp program. We also collect the engineering journals that children are provided during the experience. The feedback from educators and site observations directly inform revisions of the curricula prior to public release.

Educators rate the OST units very highly. Surveys of 118 people downloading the Bubble Bonanza EA unit showed 95% of downloaders rating the unit's ease of use as a 5, 6, or7 on a 7 point scale (1 = "not at all easy," 7 ="very easy"). Those surveyed also rated the overall quality of the unit as high, with 100% of survey respondents rating the unit a 5, 6, or 7 (1 = "very low quality," 7 = "very high quality"). All respondents indicated that they would also like to implement other EA units (Higgins, Hertel, Lachapelle, & Cunningham, 2013). Similar surveys are being gathered from downloaders of other EA units and will be also be implemented for the EE units when they are available for download.

The data collected from the Engineering Attitudes instrument suggests that children participating in EA units may experience similar changes to children using EiE. Children participating in EA pilot testing in camps during the summer of 2012 showed a significant increase from pre- to post-test in agreement with the statements "I would enjoy being a scientist when I grow up," "I would enjoy being an engineer when I grow up," and "Engineers help make people's lives better as part of their jobs" (n=476) (Higgins et al., 2013). Further analysis is currently underway on the attitudes data from EA and EE.

Qualitative analysis of the journals also suggests that participating in EA's design challenges supports children's practice of developmentally appropriate engineering practices. Most children participating in the Bubble Bonanza EA unit were able to make designs that met their stated goals, and nearly all of them seemed to incorporate what they learned while exploring the properties of the materials (Higgins et al., 2013). Anecdotal evidence gathered while observing the culminating showcase of the design challenges reinforces that children are authentically engaging in engineering practices and reflecting on the engineering design process while participating in EA.

Other Research

We are fortunate that other researchers across the country have begun to use and study the EiE program—we plan to enrich our program with results of their studies. Two of these studies are briefly described below.

A small, qualitative study in low-income high-minority urban settings in North Carolina is exploring how student and teacher ideas of "smartness" in the classroom may change as students and teachers begin to engage with EiE (Hegedus, Carlone, & Carter, 2014). Students considered "smart" in engineering exhibited different qualities (e.g. persistence, creativity) than those considered "smart"—high achievers—more traditionally. This led to some students who were low or moderate achievers generally becoming considered "smart engineers", surprising their teachers and other students.

A mixed-methods study focused on teachers' and students' views of failure in the context of the classroom and new implementation of engineering (Lottero-Perdue & Parry, 2014). Researchers interviewed 38 teachers who were randomly assigned to implement either EiE or a comparison engineering curriculum about their perspectives on failure and found that while failure is something teachers generally want to avoid in education, as it is generally associated with assessment and accountability, the experience of implementing engineering in the classroom may lead teachers to reconsider how they think about the concept of failure, especially as it may lead to growth and valuable learning experiences. "Failure" as a term has different meanings and connotations in the contexts of education and engineering, and teachers struggled with this cultural shift.

Ongoing Efforts

EiE staff and external evaluators continue to evaluate and research the Engineering is Elementary project. Student assessment continues as part of the development process to ensure that each unit as designed and implemented can, in fact, meet its stated learning objectives. EiE's evaluation process continues to evolve (Lachapelle & Cunningham, 2010). A number of the pilot studies reviewed here have revealed very interesting, sometimes unanticipated effects of the EiE materials and professional development and merit detailed, larger-scale studies that we hope to conduct. We are currently undertaking a rigorous, NSF-supported efficacy study that further examines EiE impacts on students and teachers by making direct comparisons with other curricula. Results of this study will be available by 2017.

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