Research and Evaluation Results for the *Engineering is Elementary* Project: An Executive Summary of the First Four Years

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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 four 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.mos.org/eie/research_assessment.php

Conceptions of Engineering

Student Conceptions:

An instrument—the Draw an Engineer Test—probed children's (N=384) 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). [1]

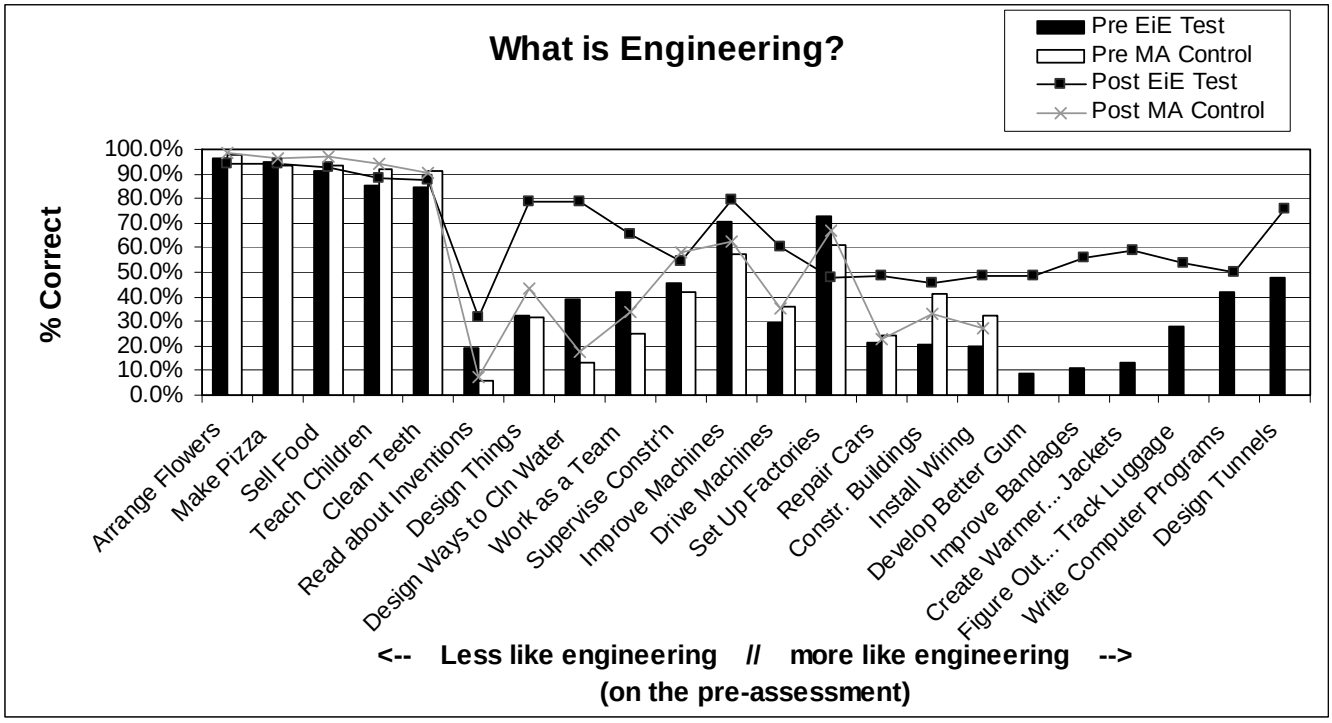
To more systematically probe children's conceptions of engineering the EiE team developed the "What is Engineering?" instrument that included captioned images of people working and asked students to choose those items that an engineer would do at work. Students were also asked to respond to the open-ended 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 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". (See Table 1). [2]

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 Table 1). [2, 3]

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. [4]

Table 1: Elementary Students' Conceptions of Engineering



Conceptions of Technology

Student Conceptions:

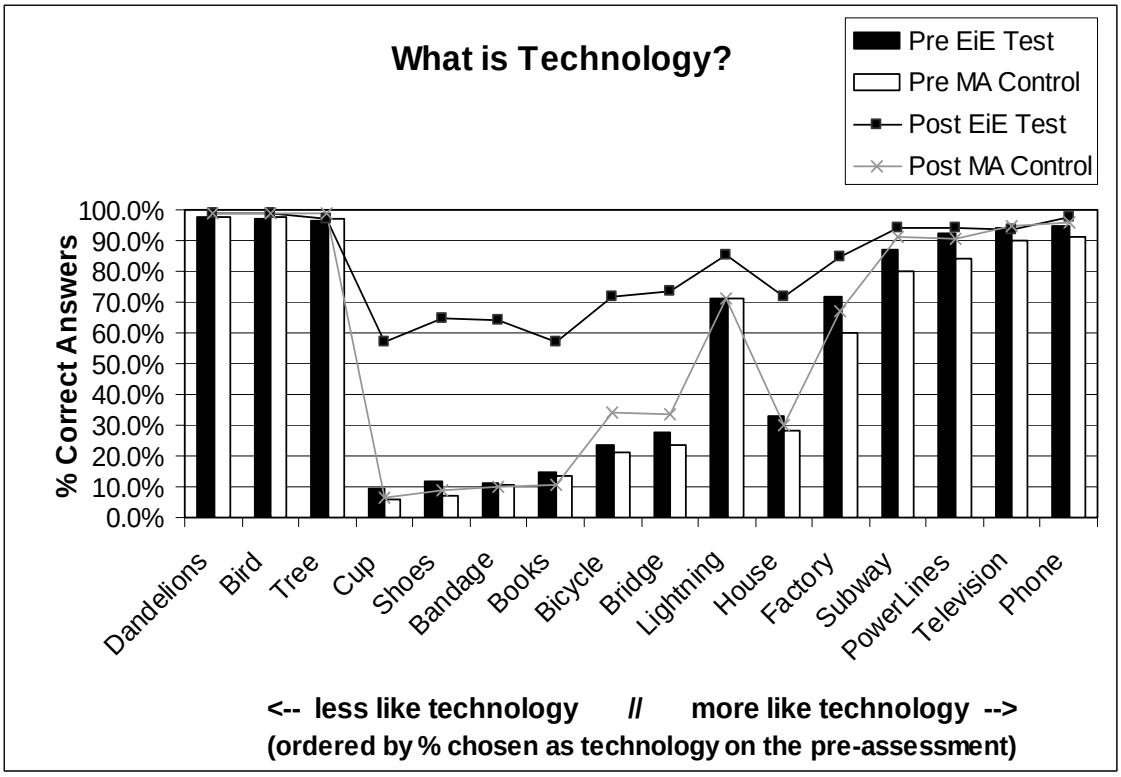
A "What is Technology?" instrument that asked children to choose which captioned items were technology was also developed by the EiE team and administered to nearly 7,000 grade 2-5 students across the country. In general, children identify technology with items that run on electricity and power [2, 3] 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. [3]

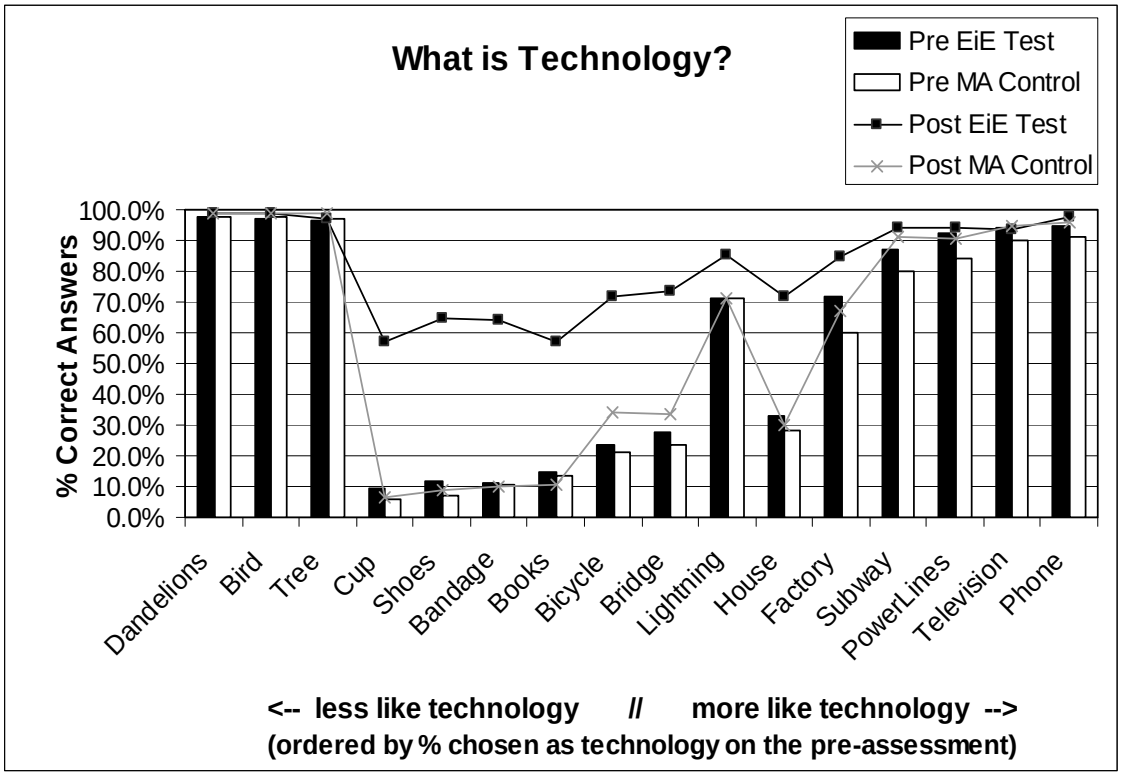
Pre- and post-assessments of a national sample of students engaged with EiE materials when compared with a control group in Massachusetts that did not use EiE demonstrate that the EiE curriculum has a dramatic, significant impact on broadening students' understanding of technology (see Figure 2). After completing an EiE unit, students are significantly more likely to indicate that common-place, human-made items are technology. [3]

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. [4]

Figure 2: Elementary Students Conceptions of Technology





Impact of EiE on Student Understanding

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. Some questions measure general engineering and technology concepts. Assessment questions are also specific to the engineering field of focus in that unit, engineering and technology concepts that are taught in the unit, and understanding of the relevant science concepts that are reinforced by engineering activities. Thus far, student results from the pre-post-assessments of the first six EiE units have been analyzed [5]. 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. After completing an EiE unit, students demonstrate:

- 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.

Teachers' Perception of the EiE Curriculum

Teachers rate the EiE curricular materials highly [6-8]. Teachers (N=162) strongly and significantly agreed that EiE units are well designed, that the EiE units 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. [8]

Teachers report 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 [9]. Of all these populations teachers agreed most strongly that the curriculum worked well with children of color. [9]

After using the EiE materials with their students, teachers (N=24) highly rate aspects of EiE indicating that they would do the unit again with their class, that they found the directions clear and felt comfortable leading the lessons, and that the science and literacy connections were useful. Overall they found that the materials for the activities were easy to get and that students were able to successfully complete the design challenge. [6]

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. [10]

When asked to compare their experiences teaching EiE and traditional elementary science curricula 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. [9]

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. [7]

EiE staff have offered close to 200 professional development programs to well 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 are Satisfied with Professional Development Programs

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. [8]

Teachers Report Large Gains in their Engineering Knowledge

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 [8, 9]. 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. [6]

Teachers Change 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 [9].

For years, educators have been trying to help teachers develop children's problem-solving capacity. EiE seems to offer one successful possibility. External evaluations [6, 8, 9] 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 [9, 10]. 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 everyday life in solving problems, work on problems for which there is no immediately obvious method of solution, and explain how they solve complex problems [9].

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."

Ongoing Efforts

EiE staff continue to evaluate and research the Engineering is Elementary. Student assessment continues as part of the development to ensure that the unit as designed and implemented can, in fact, meet its stated learning objectives. During 2007-8 we are testing an initial instrument designed to probe whether and how students' attitudes toward STEM careers change. In the coming year, we hope to create some central research and evaluation questions to be used by EiE professional development providers and researchers nationwide so we can centralize some of our collective learning through similar instruments. A number of these pilot studies 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. Finally, we are also fortunate that a number of 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.

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