

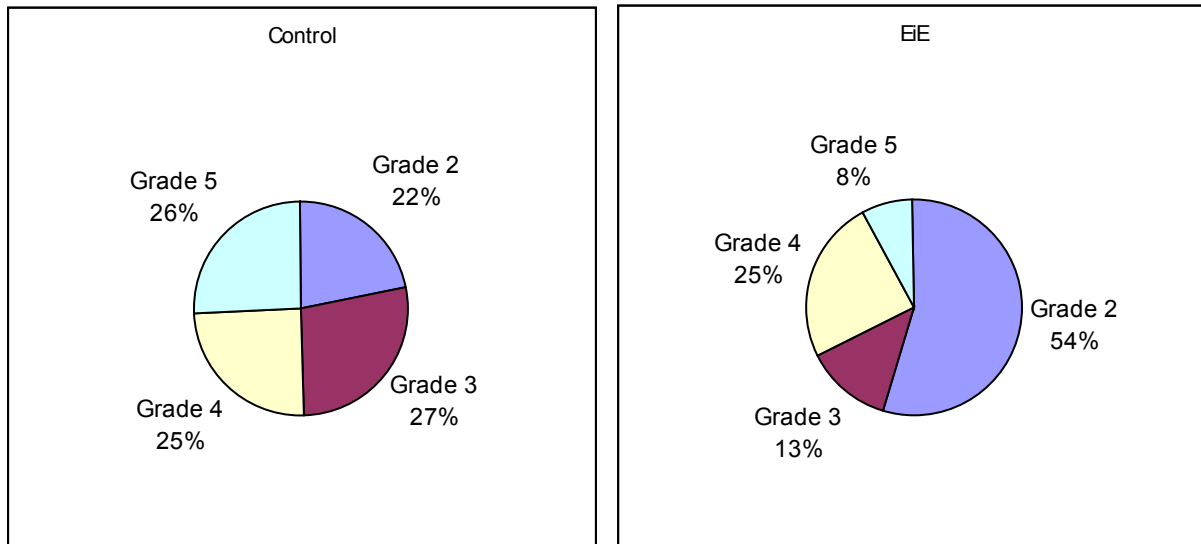
Assessment Report for Engineering is Elementary

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An important part of creating a new curriculum is assessing whether students are learning the concepts that the materials purport to teach. And to do this, one must create and test assessment item questions. A very small pre/post pilot study of some technology and engineering assessment items in 2004-5 suggested that students engaging with the Engineering is Elementary (EiE) materials had made significant gains. During the academic year 2005-6 EiE sought to investigate student learning in more depth.

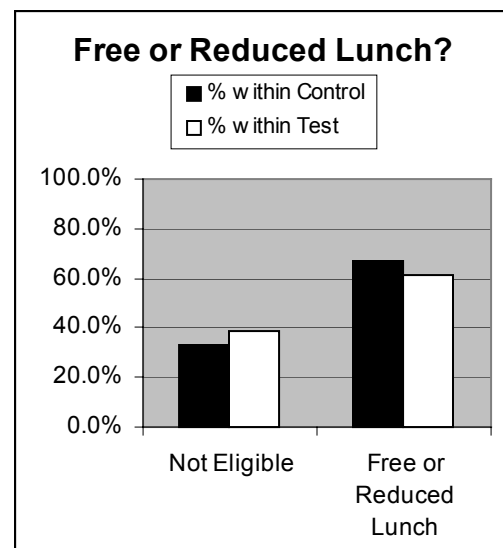
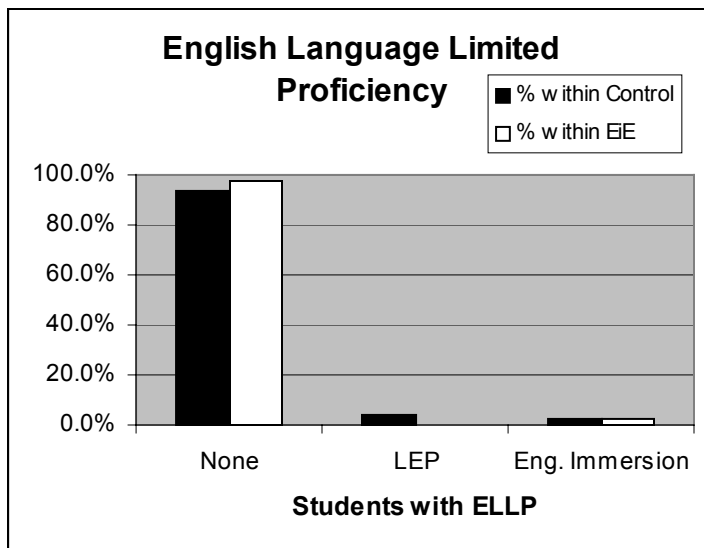
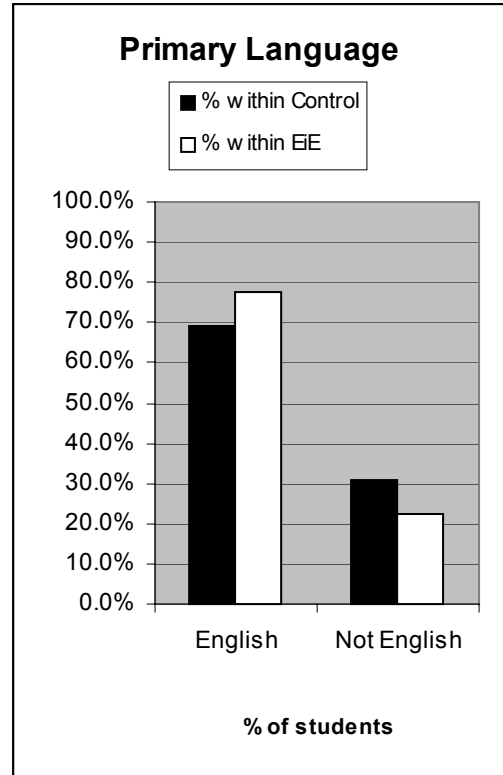
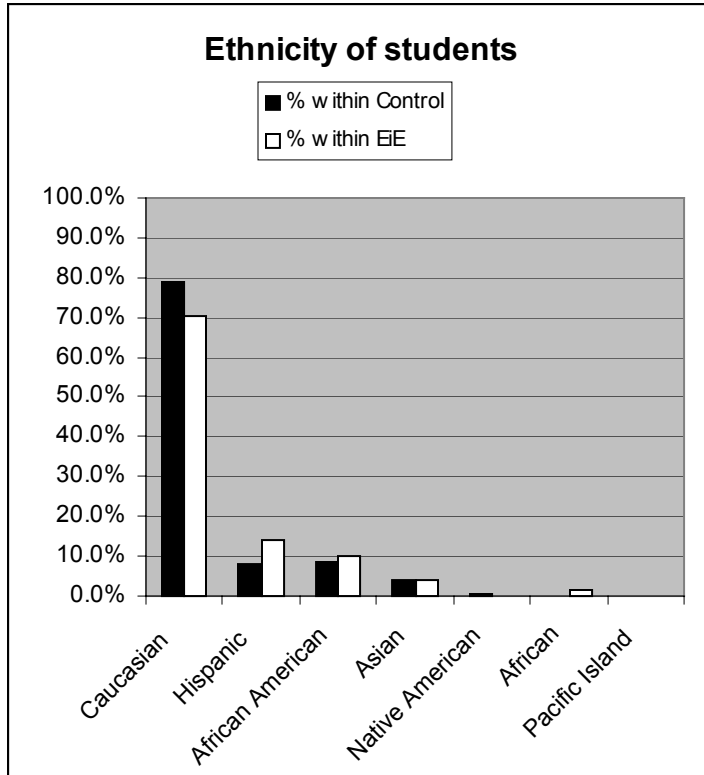
Primarily the EiE project was interested in measuring student learning with respect to engineering and technology concepts as these concepts are what the curriculum aims to teach. Thus, we developed or modified surveys that measured students' understanding of engineering, technology, engineering/technology vocabulary, and MCAS questions on engineering. To learn whether or not change in understanding was linked to use of the EiE materials, we collected data from two groups of students—"EiE Group" who used our materials and "Control Group" who did the pre and post surveys but did not use the EiE materials or study engineering and technology in their classroom.

The Control and EiE student populations differed in several key demographics. Our Control sample included almost equal numbers of students from grades 2 through 5, but no Grade 1 students. Our EiE population was made up of classrooms where teachers volunteered to test the EiE materials and to collect data from students. Because this past year we happened to have a large number of Grade 2 classrooms, the EiE student population is skewed towards younger students.



In other demographics, the two populations differ much less dramatically. The EiE population includes more ethnic minorities than the Control population, most notably 5.7% more Hispanic

students and 1.7% more African American students. 7.4% more EiE students have English as their primary language, and 3.9% fewer EiE students have limited English proficiency. And 5.2% fewer EiE students were eligible for free or reduced lunch. However, the proportion of males (48.4%) to females (51.6%) was the same for both Control and EiE student populations.



We collected data with pre and post student surveys. We asked the teachers to administer a pre-survey to their students toward the beginning of the school year or before they engaged with the EiE materials. Post-surveys were administered at the end of the school year.

For this analysis, we decided to drop all Grade 1 assessments. We did not collect Grade 1 assessments from Control classrooms at all, because we have found in the past that Grade 1 responses are not as reliable as those of older students. Though many Grade 1 classrooms used EiE materials and completed our pre- and post-surveys this year, we have decided not to compare their responses with the Grade 2-5 responses, because we found that Grade 1 responses are significantly different from those of older students.

Because some of our pilot teachers felt that their students' learning of science content improve more when they used the EiE materials as compared to when they did not, we also began a first pilot study to look at the effect of EiE materials on science learning. However, complete analysis of this group cannot take place until (a) we get additional information from the control teachers about which science units they taught last year (we are still working on securing this information), (b) we get additional surveys to increase the EiE population size (when broken down into individual science questions, the sample becomes too small to run very meaningful statistics) and (c) we can do an analysis by pair pre-post data by individual, which requires significant data manipulation. We will engage in preliminary science content analysis this winter. We will continue to collect surveys about students' science learning (in fact we have tripled the number of questions in this year's sample) and will run more robust analyses next spring.

What is Engineering?

This study grew from a previous study that probed students' conceptions of what engineers do. We modified the "Draw A Scientist Test" to focus on engineering as a "Draw an Engineer Test (DAET)." Respondents were asked what engineering is, were asked to draw a picture of an engineer at work, and then were asked describe in their picture in writing. Over 900 students Grades K-12 have completed the DAET instrument.

Reviewing students' conceptions and misconceptions about the work that engineers do from the DAET instrument, we then create the What is Engineering instrument so we can collect more quantitative and reliable data. We created a table with 16 images and descriptions of people at work and asked students to circle the kinds of work that engineers do. (A copy of the instrument is included in the Appendix.) Pictures were included to help early readers and English language learners. The final items included:

- Improve machines
- Supervise construction
- Set up factories
- Construct buildings
- Drive machines
- Arrange flowers
- Read about inventions
- Design ways to clean water
- Work as a team
- Make pizza
- Install wiring
- Sell food
- Repair cars

- Design things
- Clean teeth
- Teach children

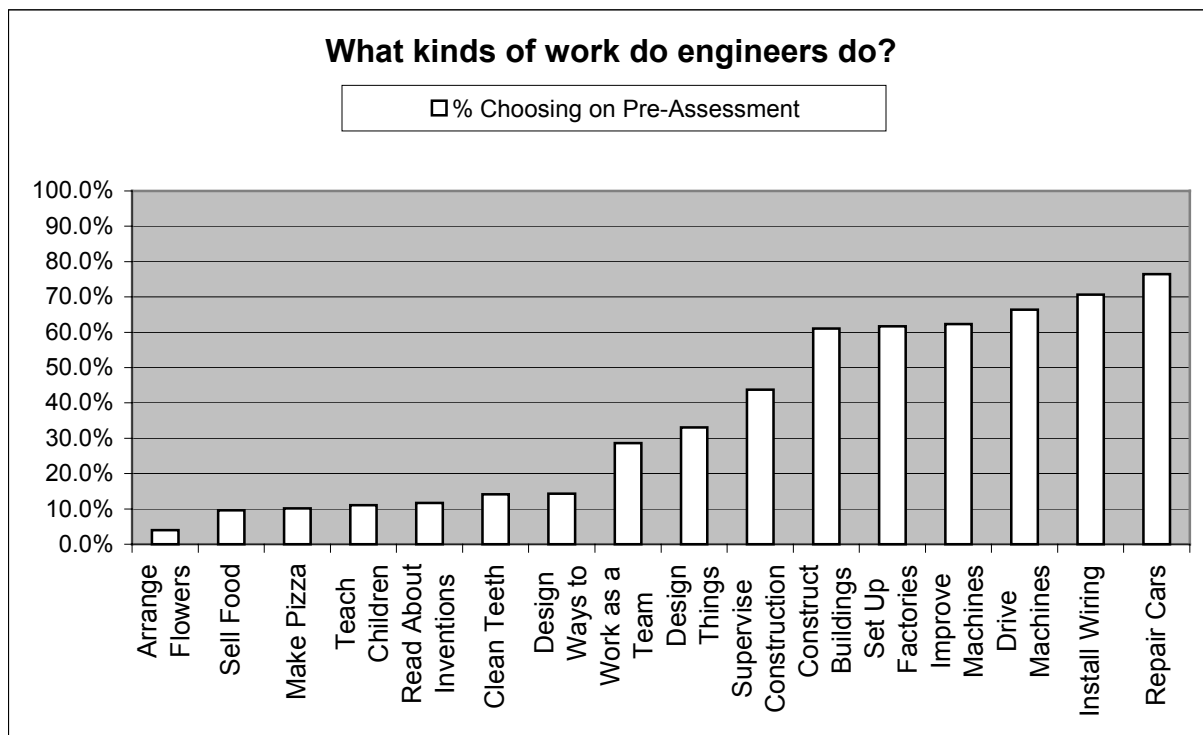
The children were also asked to complete in writing the phrase “An engineer is a person who”

Both the *What is Engineering* and *What is Technology* instruments were designed to be complex and nuanced. We hoped to use them as a measure of what students were learning over time and with increasing exposure to EiE. Thus, we hope to measure continual gains over a couple of years; we do not expect students to get all the correct items after the first exposure to EiE.

Student Pre-Conceptions of Engineering

We were interested in concerned the types of incoming conceptions that students had, prior to any work with the engineering curriculum. Graph 1 shows the results of analyzing student pre-conceptions of engineering based on the *What is Engineering* instrument. The table includes both

Graph 1: Elementary Students’ Pre-Survey Responses to *What Is Engineering?*



EiE and Control group pre-data combined. When asked to choose what kinds of work engineers do, over half of the students indicated that they thought engineers **repair cars** (76.5%), **install wiring** (70.6%), **drive machines** (66.4%), **improve machines** (62.3%), **construct buildings** (61.1%), and **set up factories** (61.7%). These data support DAET data that students perceive that engineers are auto mechanics and construction workers. Fewer students thought that engineers **supervise construction** (43.7%), **design things** (33.0%), and **work as a team** (28.6%). Students were least likely to associate any of these tasks with engineering: **design ways to clean water**

(14.3%), **clean teeth** (14.2%), **read about inventions** (11.7%), **teach children** (11.1%), **make pizza** (10.2%), **sell food** (9.6%), or **arrange flowers** (4.0%).

The only male and female differences found in the combined EiE and control pre-conceptions data was on the task **improve machines**, with 66% of females choosing this task as compared to 58.4% of males. In the post-survey, only two differences were found in male and female responses in the combined EiE and control data: **make pizza** was chosen by 9.1% females compared to 5.0% males, and **sell food** was chosen by 7.5% females compared to 2.5% males

Summary: The results further bolster the findings of our previous work about the incoming conceptions and misconceptions that students hold about engineering. The top six student choices of what engineers do are all rooted in activities that focus on construction, building, machinery, and vehicles, which suggests that students are identifying them as engineering based on their association with these attributes, not based on the type of work engineers do. Students strongly conflate construction workers and auto mechanics with engineers. While this is understandable (engineering has the word engine in it), it is also concerning, especially since these are fields that are not traditionally populated by women. Thus, these conceptions might be one reason for the lower number of girls that enter engineering than boys. Students' identification of engineering with civil engineering is also illustrated by this survey. While machines, factories, construction, and building all ranked high (regardless of whether people were supervising, improving, or designing or working as a tradesperson), the lack of understanding about the breadth of the fields of engineering begins to be captured by the survey. For example, students are not likely to think that engineers design ways to clean water. This suggests that much more education is needed to help children understand the range of the type of work engineers do. Only about a third of the students recognized one of the central features of engineering—design.

In order to better assess the degree to which students understand the range of types of engineering, we have now modified the survey and replaced half of the six items that focused on machinery and construction with items that reflect other engineering fields such as chemical, materials, and biomedical engineering. (A copy of the revised instrument is included in the Appendix.) We hypothesize that students will not recognize these disciplines as engineering.

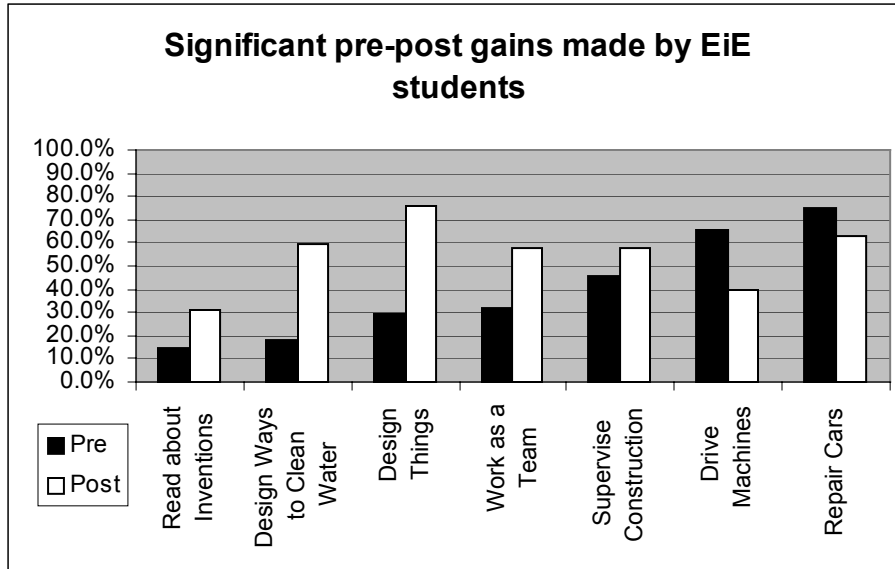
EiE Improvements from Pre- to Post-Survey

Do students who have used the EiE curriculum show gains in their understanding of engineering? Graph 2 shows the results of this analysis. EiE students were more likely to identify correct engineering tasks on their post-survey than on their pre-survey. Significant improvements were found from pre- to post- assessment on four of the six engineering tasks: **read about inventions** (from 14.6% to 31.1%), **design ways to clean water** (from 17.8% to 59.5%), **design things** (from 29.7% to 75.8%), and **work as a team** (from 31.9% to 57.4%). Though the change from pre- to post-survey was not significant, on the two other engineering tasks, **improve machines** (75.3%) and **setup factories** (66.3%), over 65% of EiE students correctly selected these by the post-test.

In addition, two of the tasks that a majority of students associate erroneously with engineering, **drive machines** and **repair cars**, are chosen significantly less often by EiE students on the post-

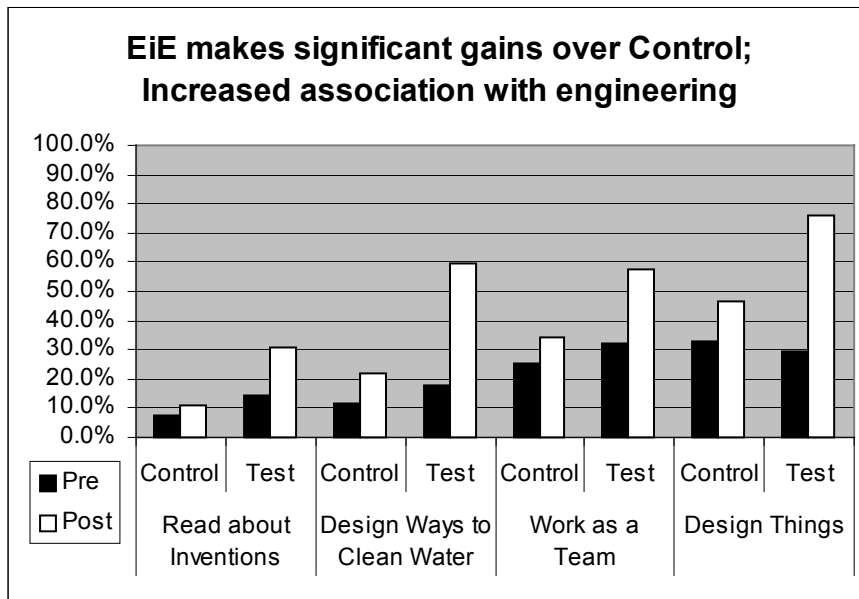
survey. The number of EiE students who associate **drive machines** with engineering drops from 65.9% to 40%. The number of EiE students who associate **repair cars** with engineering drops from 75.1% to 63.2%.

Graph 2: Engineering Tasks for Which EiE Students Show Pre- to Post Improvements

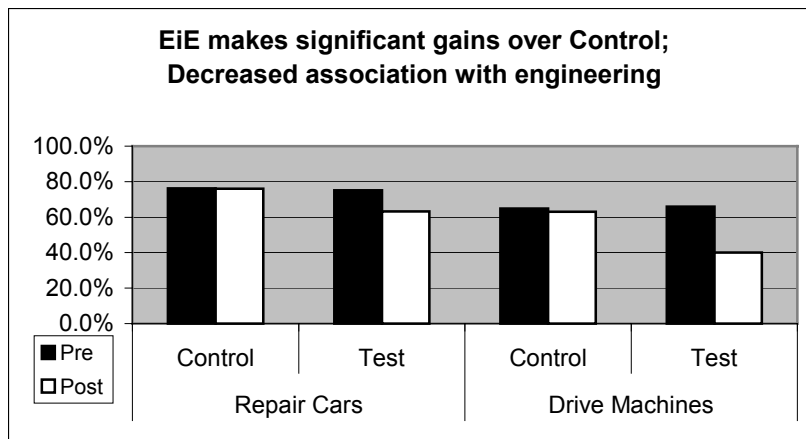


In checking for improvement within the EiE group, a stronger test of improvement due to EiE materials is whether EiE students showed significant changes in their views of what constitutes engineering from pre- to post assessment as compared to the Control students. Graphs 3 and 4 below show tasks for which significant differences occurred between the Control and EiE Groups from pre- to post-assessment. The results shown in Graph 3 indicate that in post-surveys, the EiE students showed significant improvement in their ability to associate four of the six engineering tasks with engineering as compared to the Control students. Conversely, Graph 4 shows that two of the items that a majority of students associate erroneously with engineering as pre-conceptions, **repair cars** and **drive machines**, are shown on the post-test to be chosen significantly less often by EiE students as compared to Control students.

Graph 3: EiE Students Show Significant Engineering Pre- to Post Improvements Compared to Control (Increased Association with Engineering)



Graph 4: EiE Students Show Significant Engineering Pre- to Post Improvements Compared to Control (Decreased Association with Engineering)



Summary: Overall, the data indicate that by post-test, over 50% of all EiE students correctly identified 5 of the 6 engineering tasks, and significantly improved from pre- to post in their ability to identify the 6th correct engineering task (the **read about inventions** task, which improved from 14.6% to 31.1%). By post-test over 50% of Control students were correctly identifying only 2 of the 6 engineering tasks: with **improve machines** at 62.2% and **setup factories** at 66.3%. Further, a significant number of EiE students corrected two of their engineering misconceptions from pre- to post (**repair cars** and **drive machines**).

Open-Response Questions to What Do Engineers Do?

We also coded the student responses to the open-ended question: “And engineer is a person who...” A few major categories of codes emerged from students’ responses. The most commonly cited response was that engineers fix things. When students were more specific than “things” they indicated that the items that were fixed included buildings, cars, electricity/wiring, phones, motors/engines and technology.

*“I think that sell food and repair cars are an engineer because they both work like it”
“works with special technology to fix things”*

Second most commonly students indicated that engineers build things. Again, specificity about what was being built primarily included buildings and wiring.

“bills thing and wacks as a team. And most are boys.”

“Makes stof and brakes stof.”

“An engineer is some one how does lectrisady.”

Reciting examples in the table or indicating they didn’t know was the third most generated response. That engineers work with or on things was also common. General attributes of engineers such as people who have a job, people who work with other engineers, people who work hard, and people need science and math were also recognized.

“Has a vevry in porting job.”

“is very, very very smart at math”

Some students also recognized that engineers design or improve things. A pre-post analysis by individual of students’ open-ended responses will occur later this year.

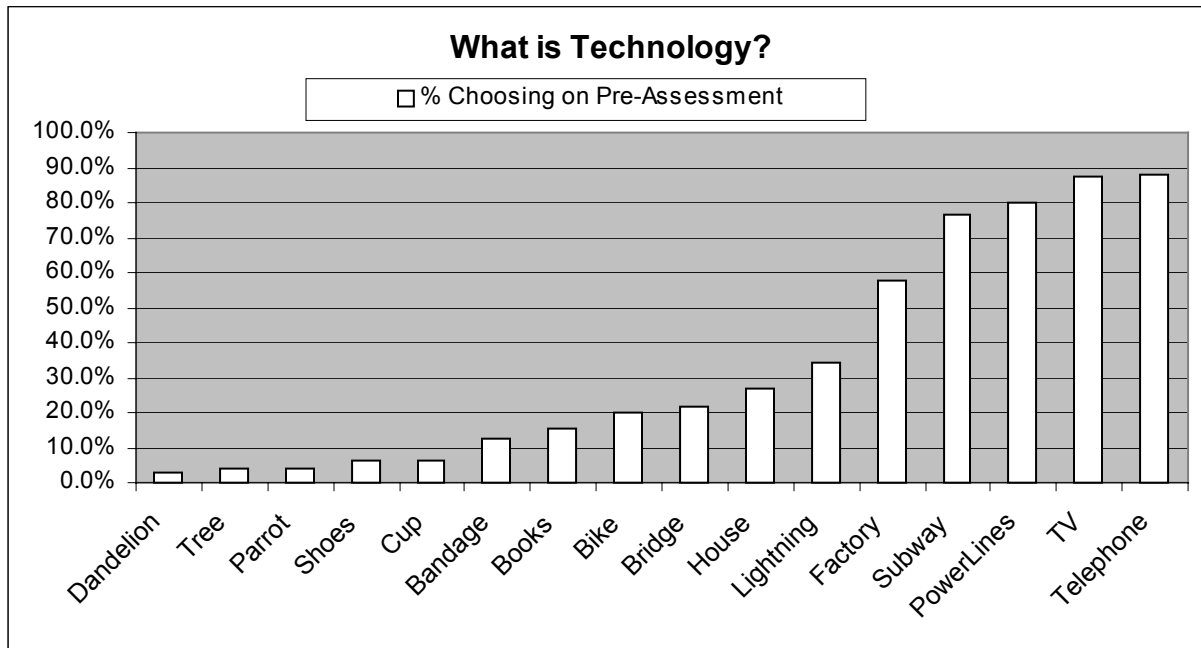
What is Technology?

We also created an instrument to measure students’ conceptions of technology *What is Technology?* The technology table contained 16 images and descriptions and asked students to circle those items that were technology. (A copy of this instrument is also included in the Appendix.) The items included four which were not technology (**oak tree, dandelion, parrot, and lightning**); four small non-electric examples of technology (**cup, shoes, bandage, books**); one small mechanical example of technology (**bicycle**); three large structural examples of technology (**bridge, house, factory**); one large transportation example of technology (**subway**); one example of power technology (**power lines**); and two electricity-based examples of technology (**television, telephone**).

Student Pre-Conceptions of Technology

Students’ pre-survey selections of examples of technology indicate that there are items that they strongly associate with technology. As Graph 5 represents, students are most likely to indicate something is technology if it requires power. **Television** (87.4%), **telephone** (88.0%), **power lines** (79.7%), **subway** (76.8%), and **factory** (57.6%) were most frequently chosen as examples of technology. One of the roots of these choices, that they require electricity, evinces itself as a misconception in 34.6% of students’ identification of **lightning** as technology. Less common responses include **house** (26.6%), **bicycle** (20.3%), **bridge** (21.9%), **books** (15.4%), **bandage** (12.3%), **shoes** (9.2%), and **cup** (8.0%). The items that are not examples of technology were also those least likely to be chosen by students: **oak tree** (5.4%), **dandelion** (4.8%), and **parrot** (3.8%).

Graph 5: Students' Preconceptions of Technology



Girls were slightly more likely than boys (both on the pre- and on the post-assessments) to express an understanding of technology that is consistent with the standards. On the pre-assessment, girls were significantly more likely to say that **subway**, **telephone**, and **bandage** were technology; they were significantly less likely to say that **dandelion**, **parrot**, and **lightning** are technology. On the post-assessment, girls chose **telephone** and **bicycle** significantly more frequently than boys, and they chose **lightning** significantly less frequently.

EiE Improvements from Pre- to Post-Survey

As Graph 6 and Table 1 represent, the post-survey responses of students who engaged with the EiE curriculum (EiE group) differed significantly from those of students in the control group. The EiE students showed significant improvement between the pre and post survey as compared with the Control students with respect to the following: they chose **lightning** less often, and they chose items that were not driven by electricity such as **books**, **shoes**, **cup**, **house**, **bandage**, and **bicycle** as technology considerably more often than Control students.

Graph 6: EiE Students Show Significant Technology Pre- to Post Improvements Compared to Control

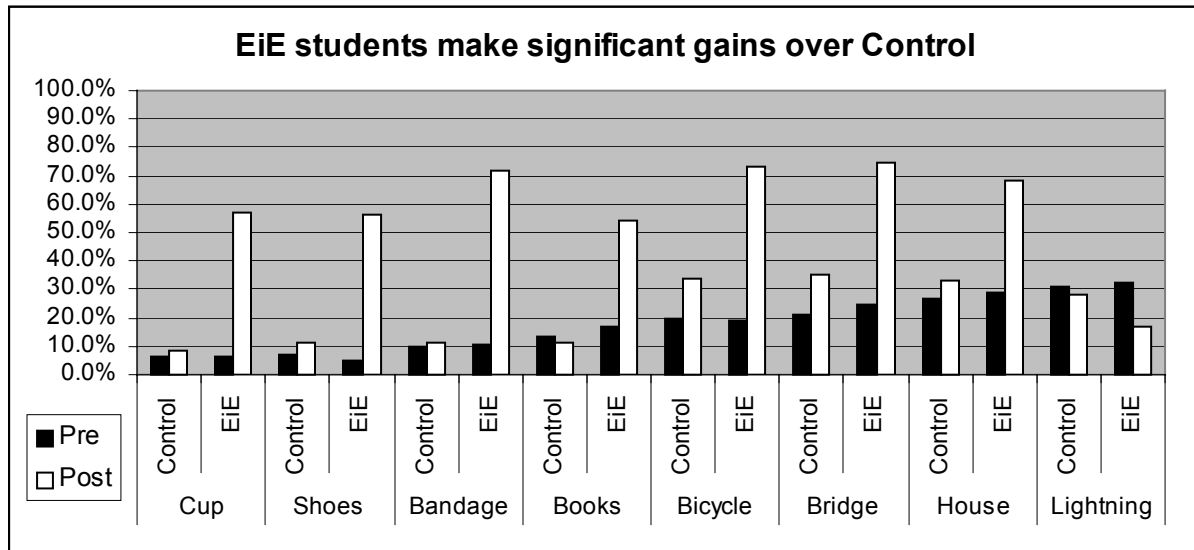


Table 1: Pearson Chi Square Tests for Significant Differences for Students Technology Responses

	Within Control Pre-Post Differences	Within EiE Pre-Post Differences	Within Pre-Control-EiE Differences	Within Post-Control-EiE Differences
Cup	0.212	0.000*	0.904	0.000*
Shoes	0.036	0.000*	0.307	0.000*
Bandage	0.483	0.000*	0.950	0.000*
Books	0.323	0.000*	0.210	0.000*
Bicycle	0.000*	0.000*	0.858	0.000*
Bridge	0.000*	0.000*	0.282	0.000*
House	0.027*	0.000*	0.493	0.000*
Lightning	0.378	0.000*	0.721	0.001*

*Significant results $p < .002$

The pre-post differences between Control and EiE students for the items items that requires power such as **power lines**, **TV**, and **cell phone** are much less clear. There were significant differences between Control and EiE students, but these appear to be because of differences in pre and post surveys combined, because overall pre and post answers are similar for both Control and EiE students.

Summary: These results indicate that engagement with the EiE materials, even one unit, increases students’ understanding of what technology is, broadening it from a focus on electricity and power to one that encompasses the human-made world.

Open-Response Questions to What Do Engineers Do?

Students were also asked to respond to the open-ended question “How do you know if something is technology?” in writing. Students’ open-ended responses on the pre-assessment to how they knew something was technology most commonly cited the fact that it uses or has electricity.

Responses such as:

“I think I know because I think that technology is something with power or electricitay”

“stuf that thay did not have in the old day's that runs on elechric”

“I know technologh because you need to plug it in that is why I know.”

“it works by bataries or by a plug. A lot of the time you miteuse a charger.”

“I think I know because these thing work on electricity. These thing can eletrify you.”

were extremely common. The second most cited set of reasons had students referencing their knowledge—they recited specific examples, indicated that they were smart “I no cus I am smart”, or admitted that they didn’t know. Students responses also referenced what the function of the technology was, for example, helping you, learning from it, or the ability to use it

“Technology is something that makes you learn like books and a computer.”

“technology is something that makes it easyer for people so they won't have to do all that stofe”

Other students explained that they knew it was technology because it was created by people.

“you can find out if something is technology if it is made by human minds”

“I know if something is technology because it takes lots of men to build something and because it takes a very long time.”

Technology/Engineering MCAS and Vocabulary Questions

To assess whether the EiE curriculum was in solid alignment with the Massachusetts Technology/Engineering framework and MCAS exam, we gave students in grades 3 to 5 four technology/engineering questions taken or adapted from past MCAS exams. Three of these questions were multiple-choice; one was open-response. We report here the results from the multiple-choice questions, because the open-response question requires further coding before it can be analyzed. Also, because we only asked this question of students in grades 3-5, the EiE sample size is too small to be profitably compared with the Control group; for this reason, we report here only EiE results. Results including Pearson chi-square tests for significance are summarized in Table 2; EiE students made significant gains on two of the three multiple-choice questions. The results for the two significant questions are displayed in Graph 7 below. There were no significant differences on the performance of male and female students for these items.

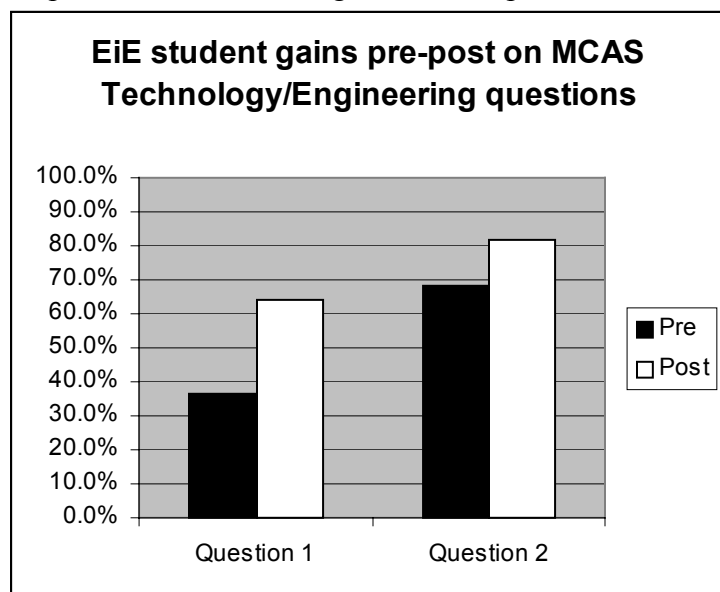
Table 2: EiE Students: Pre-post Gains on MCAS Questions

		% Correct		
		Pre	Post	P=
Question 1	Below is a picture of the drum that students in a 4 th grade class are going to make. In order for	36.4%	64.0%	0.000*

	the students to make music, the material they use for the top of the drum must be (A. flexible).			
Question 2	Which item below is NOT made from a material grown in nature? (C. a plastic spoon)	68.2%	82.0%	0.033*
Question 3	In order to build a wooden table, which of the following is the best thing to do first? (D. Make a drawing of the table.)	82.8%	82.0%	0.898

*Significant results $p < .05$

Graph 7: EiE Students: Significant Pre-post Gains on MCAS Questions



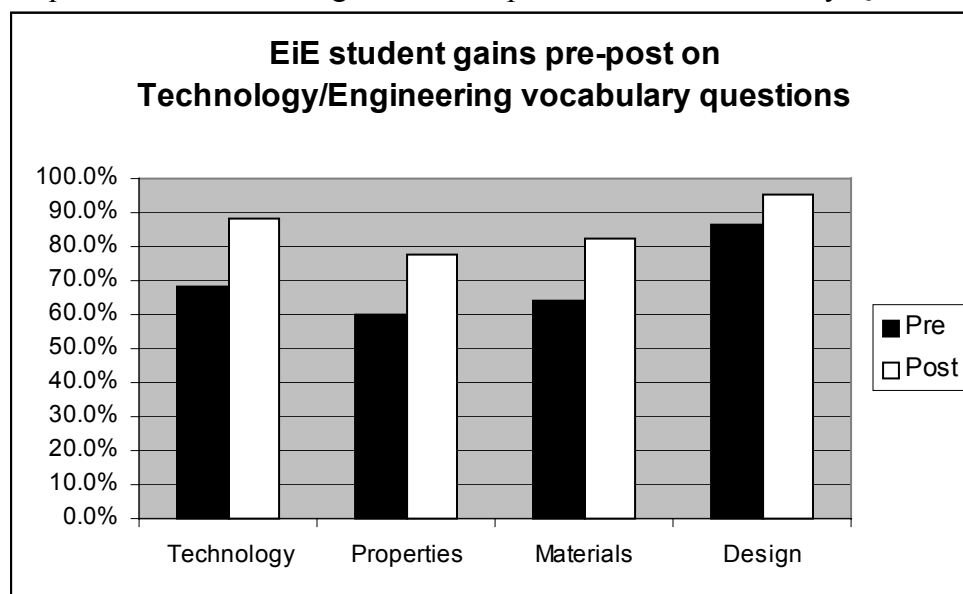
Our pre and postsurveys also asked students in Grades 3-5 a page of vocabulary questions related to engineering and technology. EiE students made significant gains on four out of five of the questions. The results are summarized in Table 3 and Graph 8.

Table 3: EiE Students: Pre-post Gains on Vocabulary Questions

		% Correct		P=
		Pre	Post	
Properties	Some _____ of a piece of wood are how strong it is and how smooth it is.	60.2%	77.5%	0.018*
Technology	_____ is anything that people make to solve a problem.	68.1%	88.3%	0.003*
Materials	Some _____ that can be used to make roads are concrete, flat rocks, tar, and gravel.	64.0%	82.6%	0.006*
Design	When you _____ a chair, you need to think about how big and how strong it needs to be.	86.6%	95.4%	0.044*
Engineers	_____ are people who solve problems using math, science, and imagination.	82.3%	90.8%	0.106

*Significant results $p < .05$

Graph 8: EiE Students: Significant Pre-post Gains on Vocabulary Questions



Again, none of the vocabulary results were significantly different between male and female students.

Summary: Early analysis of a subset of the content questions suggests that students who have used EiE materials make significant gains on their knowledge of both related vocabulary and engineering/technology concepts.

Future Steps:

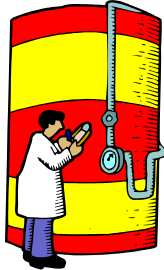
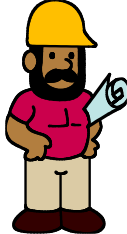
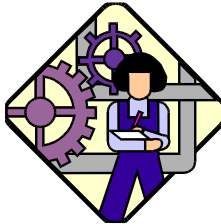
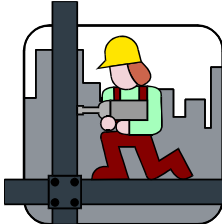






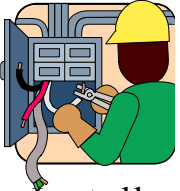

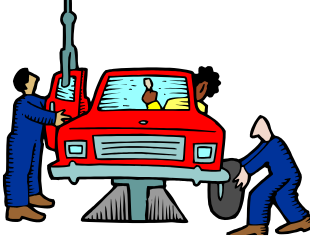
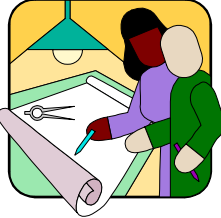

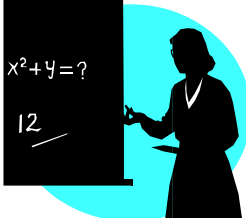
The wealth of surveys that we collected during the 2005-6 academic year provides rich information about the effects of EiE that we will continue to analyze in great detail. Further data analysis using of the larger sample of science questions when we have additional data and they and further massaged will allow the EiE team to investigate such student learning gains in more depth, and to compare them to a Control group of students.

As mentioned previously, we are also tripling the number of science and engineering content questions that we are piloting this year with students. Analysis of these data next summer will permit us to identify objects that best measure student learning.

Finally, we continue to collect pre and postsurvey information from teachers that we work with across MA and from teachers in states across the country. We anticipate that we will have pre and post student data to analyze next year from over 5000 students in 7 or more states.

What is an Engineer?

What kinds of work do engineers do? Circle the kinds of work that you think engineers do for their jobs.


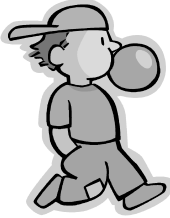

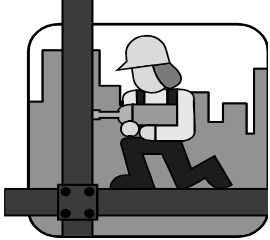
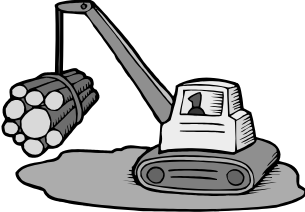





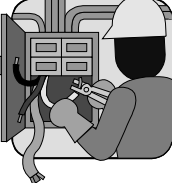

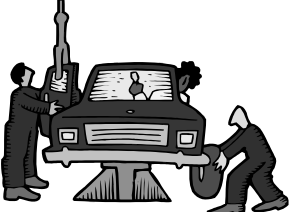



 <p>Improve Machines</p>	 <p>Supervise Construction</p>	 <p>Set Up Factories</p>	 <p>Construct Buildings</p>
 <p>Drive Machines</p>	 <p>Arrange Flowers</p>	 <p>Read about Inventions</p>	 <p>Design Ways to Clean Water</p>
 <p>Work as a Team</p>	 <p>Make Pizza</p>	 <p>Install Wiring</p>	 <p>Sell Food</p>
 <p>Repair Cars</p>	 <p>Design Things</p>	 <p>Clean Teeth</p>	 <p>Teach Children</p>

An engineer is a person who... _____

What is an Engineer?

What kinds of work do engineers do?


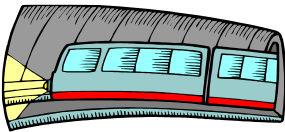




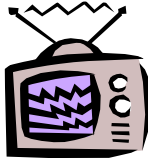


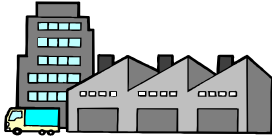

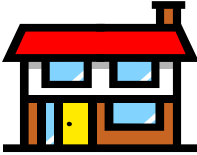




Circle the kinds of work that you think engineers do for their jobs.

 <p>Improve Bandages</p>	 <p>Develop Better Bubble Gum</p>	 <p>Design Ways to Clean Water</p>	 <p>Construct Buildings</p>
 <p>Drive Machines</p>	 <p>Arrange Flowers</p>	 <p>Read About Inventions</p>	 <p>Figure Out How to Track Luggage</p>
 <p>Work as a Team</p>	 <p>Create Warmer Kinds of Jackets</p>	 <p>Install Wiring</p>	 <p>Sell Food</p>
 <p>Repair Cars</p>	 <p>Design Tunnels</p>	 <p>Clean Teeth</p>	 <p>Write Computer Programs</p>

What is an engineer? _____

What is Technology?

Which of these things are examples of technology?
Circle the items that you think are technology.

 Shoes	 Subway	 Dandelions	 Cellular Phone
 Oak Tree	 Bridge	 Television	 Cup
 Parrot	 Factory	 Bandage	 House
 Power Lines	 Bicycle	 Lightning	 Books

How do you know if something is technology?
