The Impact of Engineering is Elementary (EiE) on Students' Attitudes toward Engineering and Science

Christine M. Cunningham
Cathy P. Lachapelle

Engineering is Elementary
The National Center for Technological Literacy
Museum of Science, Boston

June, 2010

Engineering is Elementary
Museum of Science, 1 Science Park
Boston, MA 02114

This material is based upon work supported by the National Science Foundation under Grant No. 0454526. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Abstract

This paper probes whether students' attitudes toward engineering and science are impacted as a result of using Engineering is Elementary (EiE) curricular materials. It presents results from data from an instrument that focused on measuring students' attitudes about and perceptions toward engineering. The Engineering Attitudes Survey was originally developed as an assessment of middle school students' knowledge of engineering and their attitudes toward it. The survey was adapted for EiE use. To measure the impact of EiE on students, the attitude survey was administered to a "test/EiE" group of students who used the EiE curriculum (students were taught an EiE unit and related science) and a "control" group whose students were taught related science, but did not use EiE materials. Data about student sex, race/ethnicity, and free and reduced lunch status were also collected. The attitudes instrument was administered to students in six states in a pre/post design. Results indicate that students who completed the EiE 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.

Introduction

Engineering is Elementary (EiE) is a research-based curriculum project focused on creating curriculum units covering topics in engineering and technology as a supplement to core science instruction. The curriculum aims to increase student knowledge and skills related to engineering and technology. Each EiE curriculum unit is designed to build on and reinforce one science topic through the exploration and development of a related technology. Each EiE unit has common elements, including a four-lesson structure. The first lesson introduces a field of engineering and a design challenge through a fictional story. The second lesson explores the field of engineering more broadly through hands-on activities. The third lesson includes a controlled experiment for more in-depth exploration of different materials, processes, or design elements that will inform the final design. For the fourth lesson, students plan, create, test, evaluate and improve their designs. As a result of engaging in engineering challenges and better understanding engineering concepts and being exposed to the kind of work of engineers do, some students might also report increases in their attitudes and self efficacy related to engineering and engineering careers. This paper investigates whether the EiE curriculum impacts these perceptions.

Methods

To measure elementary students' attitudes and perceptions toward engineering, an instrument was developed and administered to a "test/EiE" group of students who used the EiE curriculum (students were taught an EiE unit and related science) and a "control" group whose students were taught related science, but did not use EiE materials. Data about student sex, race/ethnicity, and free and reduced lunch status were also collected from students in six states in a pre/post design.

Student Sample

Responses from students engaged with EiE curriculum (called EiE or test below) were compared to responses from a control sample. Both the test sample and the control sample received science instruction after completing the pre-assessments and before completing post-assessments. The test sample completed the EiE curriculum in addition to their regular science curriculum.

Surveys were collected from students in California, Florida, Massachusetts, New Hampshire and Rhode Island (see Table 1). The largest number of surveys was collected from Massachusetts. Most of the surveys were completed by grade 4 and grade 5 students. A total of 1056 student surveys were analyzed; 678 were completed by EiE (test) students, and 378 by control.

Table 1. Engineering Attitudes Survey: Sample Size by Grade, by State

		CA	**FL**	**MA**	**Other**	**Total**
Grade 3	Control	15	14	19	-	48
	Test	-	-	30	8	38
Grade 4	Control	93	61	11	11	176
	Test	78	94	224	18	414
Grade 5	Control	-	37	109	8	154
	Test	-	14	194	18	226
Total	Control	108	112	139	19	378
	Test	78	108	448	44	678

Girls and boys each made up approximately half of the sample. Of the 599 EiE (test) students for whom information was available, 109 (19%) received "Free Lunch" or "Reduced Lunch" from the National School Lunch Program, as reported by their teachers.

White students made up the bulk of the sample (59.8%); Hispanic students made up 22.3% of the sample, while Black and Asian students represented 8.8% and 7.1% of the population, respectively—see Table 2***Table***. Racial/ethnic minorities were better represented in the control sample than in the EiE (test) sample. The numbers of racial/ethnic minorities in the sample were insufficient for separate analysis.

Table 2. Engineering Attitudes Survey: Sample Size by Race/Ethnicity

	Black	**Asian**	**Hispanic**	**White**	**Other**	**Total**
Control	58	42	104	150	8	362
EiE	33	31	127	468	13	672
Total	91	73	231	618	21	1034
Total (Percent)	8.8%	7.1%	22.3%	59.8%	2.0%	100.0%

The control sample also included a significantly larger proportion of students receiving free or reduced-price lunch (57.6%) than the test group (31.7%) for the Engineering Attitudes survey.

The impact of these differences on assessment results is relatively small, and is evaluated in the analysis to follow.

Instrument and Data Collection

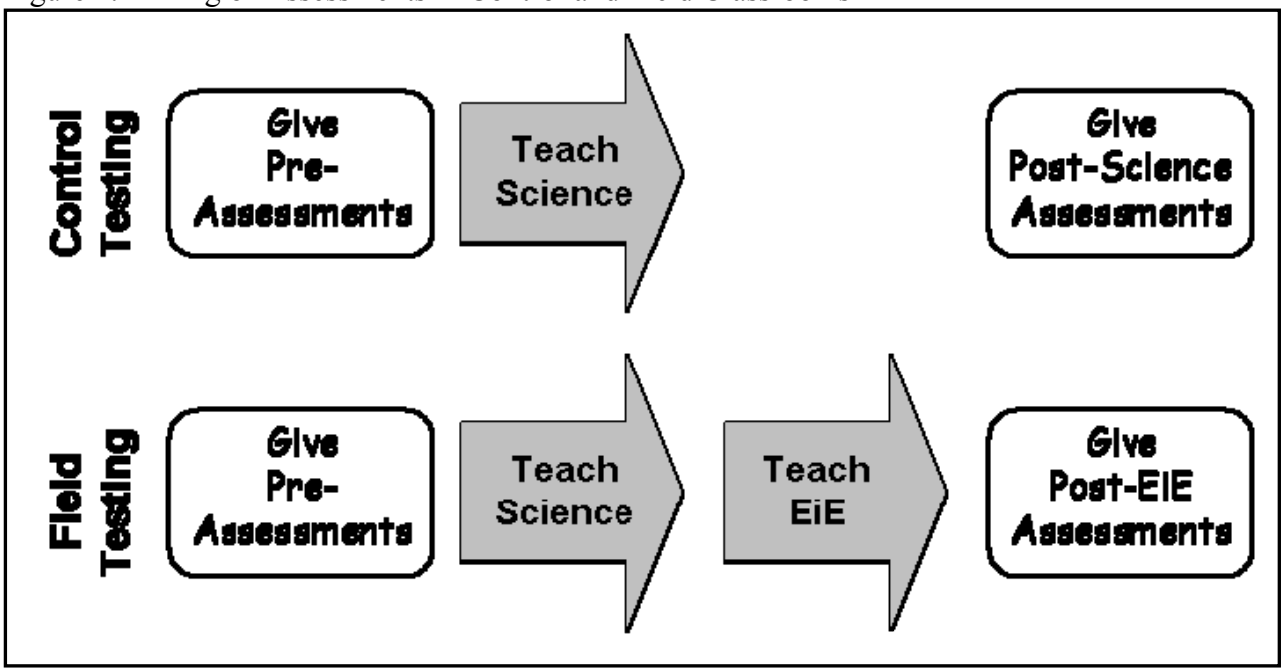
The Engineering Attitudes Survey was originally developed as an assessment of middle school students' knowledge of engineering and their attitudes toward it.[1] The survey was adapted for EiE use; some items were revised to describe work that would more clearly benefit people and society, and the response options were changed from "yes/no/I don't know" to a 5-point Likert scale where: 0=Strongly Disagree; 1=Disagree Somewhat; 2=Not Sure; 3=Agree Somewhat; 4=Strongly Agree. The revised engineering attitudes survey consists of twenty statements, in which students are asked to indicate their agreement/disagreement on the five-point Likert scale.

Each participating EiE test student and control student received an "engineering attitudes" survey as part of a larger suite of EiE assessments. Every student in a classroom received the same assessments. The engineering attitudes survey consists of twenty statements, for which students are asked to indicate their agreement/disagreement on a five-point Likert scale. Where possible, pre-assessments were given in October or November, and post-assessments in May or June of the same school year. However, due to the varying circumstances of individual teachers, sometimes the pre-assessments were given later in the school year or the post-assessments earlier. For example, some assessments were administered by science specialists who saw their students for only a portion of the year. Others were administered by teachers who first learned about the project and signed up to field test an EiE unit in January. In all cases, teachers were instructed to administer pre-assessments before instruction in any EiE unit and related science topics, and post-assessments were administered after all science and EiE instruction was completed.

Because the time period between pre- and post-assessment is larger than just a few weeks, maturation effects can be reasonably expected. One reason to include the control sample is to get a measurement of what change we can expect on the post-assessment after four to six months. As we will explain below, we often see significant improvement on the post-assessment by control students, but this improvement is rarely as large as the improvements made by students who have participated in EiE. Also, EiE students make more consistent significant improvements on assessment questions than control students.

EiE students were tested twice—once before beginning the science curriculum and/or related Engineering is Elementary unit, and once after instruction was completed—allowing for a test-retest analysis.

Figure 1. Timing of Assessments in Control and Field Classrooms



Assessment items were combined into scales to test for reliability; principal components factor analysis was run to search for item groupings. Reliability was high for the Engineering Attitudes assessment as a whole. Scales and composite scores were constructed for the assessments.

For the scales on the Engineering Attitudes assessment, items making up the scales were summed for each student, producing composite scores. These composite scores were tested for normality using the Kolmogorov-Smirnov test and the Sharpiro-Wilk test in SPSS. Since none of the scales showed a normal distribution, they were analyzed using nonparametric statistics. The Wilcoxon Signed Ranks test was used to test for within-group (pre vs. post) differences; the Wilcoxon Mann-Whitney Test was used to test for between-group (control vs. test) differences.

Results

The text of the questions on the Engineering Attitudes Survey is shown in Table 3. A variety of questions measure students' attitudes toward science and engineering careers and skills, as well as some of their attitudes towards science, math, scientists, and engineers. Items were combined into the item scales designated in the first column.

Table 3. Engineering Attitudes Survey: Survey Questions (Text)

Item Scale	Range of Scale	Text of component questions
REAL LIFE	0-8	Science has nothing to do with real life. Math has nothing to do with real life.
CAUSE PROBLEMS	0-8	Scientists cause problems in the world. Engineers cause problems in the world.
JOBS	0-64	*Consists of the sum of all of the remaining questions*
INVENT	0-12	I would like a job where I could invent things. I would like to help plan bridges, skyscrapers, and tunnels. I would like a job that lets me design cars.
HELP SOCIETY	0-12	I would like to build and test machines that could help people walk. I would enjoy a job helping to make new medicines. I would enjoy a job helping to protect the environment.
FIGURE THINGS OUT	0-16	I would like a job that lets me figure out how things work. I like thinking of new and better ways of doing things. I like knowing how things work. I am good at putting things together.
MAKE LIVES BETTER	0-8	Scientists help make people's lives better. Engineers help make people's lives better.
KNOW ABOUT JOBS	0-8	I think I know what scientists do for their jobs. I think I know what engineers do for their jobs.
SCIENTIST	0-4	I would enjoy being a scientist when I grow up.
ENGINEER	0-4	I would enjoy being an engineer when I grow up.

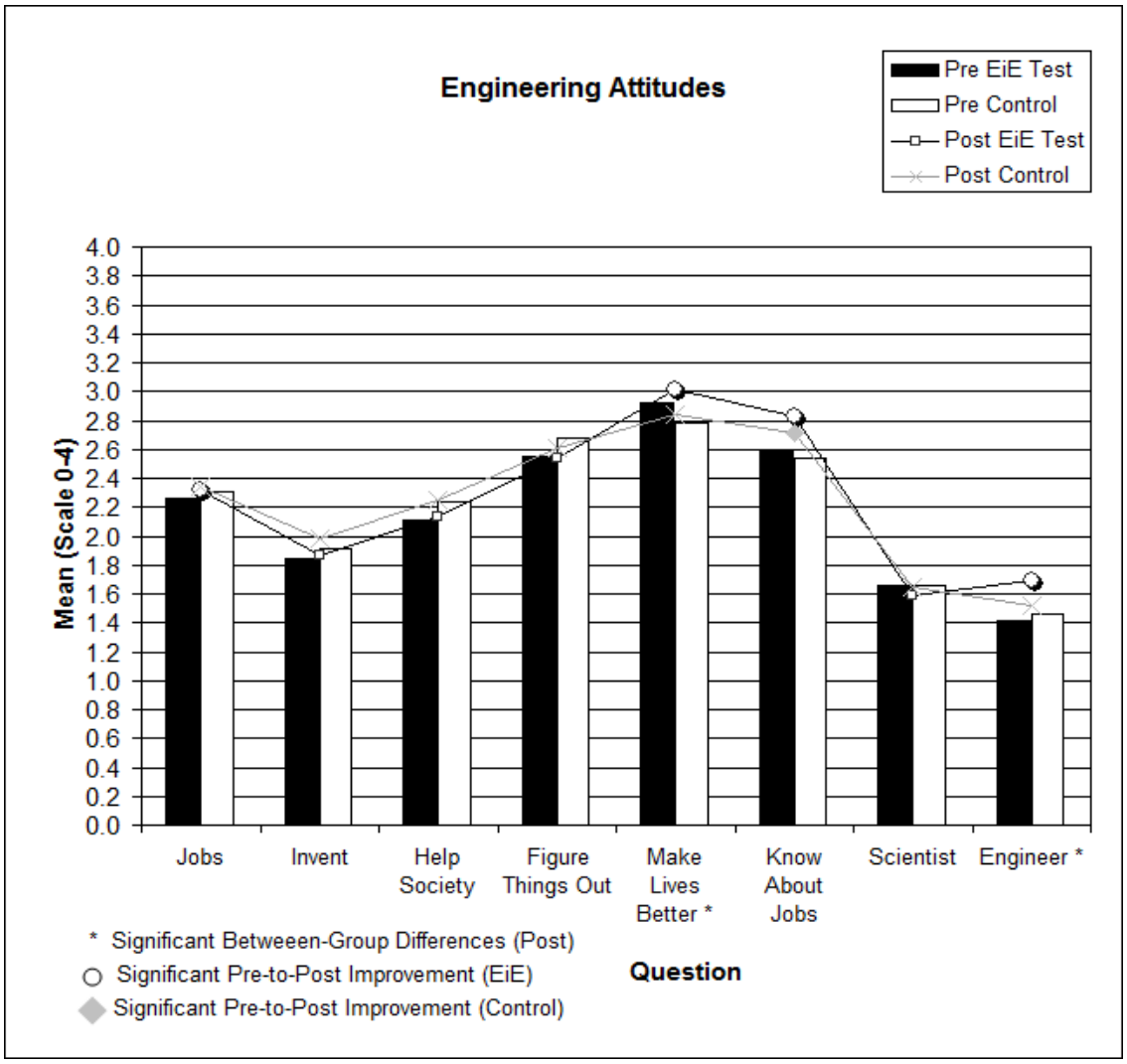
Reliability analysis shows this is a highly reliable instrument. Sixteen of twenty items were chosen as the core JOBS scale. These items all asked students about their knowledge of and attitudes towards the work of scientists and engineers, as well as their attitudes towards a variety of jobs and skills associated with engineering. Reliability Analysis of the JOBS scale in SPSS gives this scale a Cronbach's $\alpha = .833$. Additionally, we conducted a principal components factor analysis on the sixteen items of the JOBS scale with Varimax rotation. Factor analysis revealed a consistent pattern of five rotated components in the JOBS scale, each corresponding to between two and five of the twenty survey items: INVENT, HELP SOCIETY, FIGURE THINGS OUT, MAKE LIVES BETTER, and KNOW ABOUT JOBS. These five components account for 60.4% of the variance in the scale. Student responses to the items contributing to each factor were summed to create composite scores for each of the five factors, which were then used in the analysis.

The remaining four items of the original twenty were combined to form two additional scales, REAL LIFE and CAUSE PROBLEMS. Each was created from highly correlated pairs of items. The REAL LIFE scale has a Cronbach's $\alpha = .729$, and the CAUSE PROBLEMS scale has a Cronbach's $\alpha = .715$.

Two of the twenty questions were reported separately (in addition to being part of the JOBS scale) because of their relevance to the project: "I would enjoy being a scientist when I grow up", and "I would enjoy being an engineer when I grow up". These items are reported as SCIENTIST and ENGINEER.

Student responses are summarized in Table 4 and Figure 2. For each scale or item listed in the left-most column, total means and grade-level means are given for both the EiE (test) sample and the control sample. Within-group significance was tested using the Wilcoxon Signed Ranks Test instead of parametric methods because the distribution of all items was found to be non-normal. Exact significance is reported under "p=". P-values significant at p<.05 or below are highlighted in bold. Between-group significance for control versus test on the pre-survey and on the post-survey is given in the final two columns; this was tested using the Wilcoxon Mann-Whitney Test.

Figure 2. Engineering Attitudes Survey: Results



EiE students were significantly more likely to say they would enjoy being an engineer after completing an EiE unit than before (ENGINEER p<.001)—and significantly more likely than control students to say so (p<.05). They were also significantly more likely to agree that Scientists and Engineers help to make people's lives better than control students (MAKE LIVES BETTER p<.01) and than they had before doing EiE (p<.05). Overall, EiE students responded

Table 4. Engineering Attitudes Survey: Results

		Within-Group Differences (Pre vs. Post)								Test / Control Differences	
		EiE Test				Control				PRE	POST
Question	**Group**	**N**	**Pre**	**Post**	**p=**	**N**	**Pre**	**Post**	**p=**	**p=**	**p=**
Science/Math have nothing to do with REAL LIFE[2]	Total	678	1.51	1.12	**.000**	378	1.35	1.12	**.030**	.956	.826
	Gr. 3	38	**N too small to report**			48	**N too small to report**				
	Gr. 4	414	1.75	1.20	**.000**	176	1.51	1.45	.755	.690	.115
	Gr. 5	226	1.08	0.87	.336	154	0.81	0.57	.078	.567	.129
Scientists / Engineers CAUSE PROBLEMS[2]	Total	678	2.36	2.32	.684	378	2.10	2.49	**.002**	.161	.220
	Gr. 3	38	**N too small to report**			48	**N too small to report**				
	Gr. 4	414	2.27	2.28	.814	176	2.02	2.59	**.005**	.332	.093
	Gr. 5	226	2.49	2.29	.192	154	2.14	2.24	.407	.155	.839
Science/Eng JOBS—My preferences & understndng[5]	Total	675	36.11	37.13	**.015**	374	36.93	37.42	.089	.274	.853
	Gr. 3	38	**N too small to report**			47	**N too small to report**				
	Gr. 4	412	35.68	37.38	**.004**	175	38.59	37.56	.138	**.002**	.803
	Gr. 5	225	36.32	36.24	.938	152	35.28	37.68	**.005**	.290	.201
Jobs Factor 1: I like to INVENT[3]	Total	678	5.52	5.59	.550	378	5.73	5.94	.152	.285	.096
	Gr. 3	38	**N too small to report**			48	**N too small to report**				
	Gr. 4	414	5.48	5.68	.229	176	6.08	5.88	.333	**.035**	.580
	Gr. 5	226	5.39	5.29	.674	154	5.23	6.08	**.003**	.659	**.016**
Jobs Factor 2: I like to HELP SOCIETY[3]	Total	678	6.32	6.41	.473	378	6.70	6.75	.630	.094	.071
	Gr. 3	38	**N too small to report**			48	**N too small to report**				
	Gr. 4	414	6.35	6.47	.479	176	7.47	7.28	.302	**.000**	**.006**
	Gr. 5	226	6.16	6.16	.916	154	5.79	6.14	.199	.162	.874
Jobs Factor 3: I like to FIGURE THINGS OUT[4]	Total	678	10.18	10.16	.476	378	10.69	10.44	.769	**.032**	.244
	Gr. 3	38	**N too small to report**			48	**N too small to report**				
	Gr. 4	414	10.03	10.26	.552	176	11.31	10.44	**.007**	**.000**	.719
	Gr. 5	226	10.34	9.92	.071	154	10.18	10.48	.198	.627	.160
Jobs Factor 4: Scientists/Eng MAKE LIVES BETTER[2]	Total	678	5.84	6.03	**.016**	377	5.56	5.69	.089	**.019**	**.003**
	Gr. 3	38	**N too small to report**			48	**N too small to report**				
	Gr. 4	414	5.71	5.97	**.007**	175	5.54	5.40	.482	.427	**.001**
	Gr. 5	226	5.96	6.12	.400	154	5.75	6.05	**.043**	.124	.418
Jobs Factor 5: I KNOW ABOUT scientists/ eng'rs JOBS[2]	Total	675	5.16	5.65	**.000**	374	5.07	5.42	**.000**	.369	.070
	Gr. 3	38	**N too small to report**			48	**N too small to report**				
	Gr. 4	412	5.12	5.59	**.000**	175	5.06	5.28	.181	.659	.084
	Gr. 5	225	5.28	5.77	**.003**	152	5.18	5.69	**.000**	.709	.736
I would enjoy being a SCIENTIST[1]	Total	678	1.66	1.59	.163	378	1.66	1.65	.940	.990	.543
	Gr. 3	38	**N too small to report**			48	**N too small to report**				
	Gr. 4	414	1.63	1.70	.216	176	1.66	1.74	.628	.671	.824
	Gr. 5	226	1.69	1.38	**.000**	154	1.62	1.60	.848	.594	.131
I would enjoy being an ENGINEER[1]	Total	678	1.42	1.69	**.000**	378	1.46	1.52	.170	.557	**.031**
	Gr. 3	38	**N too small to report**			48	**N too small to report**				
	Gr. 4	414	1.34	1.72	**.000**	176	1.45	1.54	.498	.282	.119
	Gr. 5	226	1.53	1.61	.407	154	1.45	1.65	.053	.552	.896

[1]Scale range: 0-4. [2]Scale range: 0-8. [3]Scale range: 0-12. [4]Scale range: 0-16. [5]Scale range: 0-64

more positively to the questions about science and engineering jobs on the post-survey than they did on the pre-survey (JOBS $p<.01$).

Both EiE and control students were less likely to agree on the post-survey that science and math have nothing to do with real life (REAL LIFE Test $p<.001$, Control$<.05$). Both groups also agreed more strongly on the post-survey that they knew what scientists and engineers do for their jobs (KNOW ABOUT JOBS $p<.001$). Finally, control students were more likely to agree on the post-survey that scientists and engineers cause problems in the world (CAUSE PROBLEMS $p<.01$), while EiE students made no significant change on this item.

Differences between the control and test group on the HELP SOCIETY scale were not significant, but the control group scores on this item were higher than the test group's (with the difference close to significance). However, this was one of two questions on which students who received free or reduced price lunch (FRL) answered significantly differently than students who did not (N-FRL), with the test FRL group significantly more likely to agree on the post-assessment than the test N-FRL group. Since the control sample consists of a significantly higher proportion of FRL students, it is possible that these scores are inflated, and the control and test groups are much closer than they appear.

Gender and Free or Reduced-Price Lunch Differences

Table 5 and Figure 3 compare the responses of male and female EiE (Test) students only. Girls and boys answered significantly differently on almost all scales and items about science and engineering jobs on both the pre-survey and the post-survey. Though both girls and boys were more likely to say they would enjoy being an engineer on the post survey (girls $p<.001$, boys $p<.01$), girls started and ended less positively than boys on most scales: they were much less likely to show interest in "inventing" and engineering jobs involving cars and infrastructure (INVENT $p<.001$); they were less likely to express interest and efficacy in figuring things out (FIGURE THINGS OUT pre- $p<.01$, post- $p<.05$); they were less likely to agree that engineers and scientists make people's lives better (MAKE LIVES BETTER $p<.05$); and they were less likely to agree that they would enjoy being an engineer (ENGINEER $p<.001$).

However, girls were significantly more likely than boys to express an interest in jobs to help society such as making new medicines and building machines to help people walk (HELP SOCIETY pre- $p<.01$, post- $p<.05$). And, though they were less likely than boys on the pre-survey to say that they knew what engineers and scientists do for their jobs (KNOW ABOUT JOBS pre- $p<.05$), after completing an EiE unit there was no difference between boys and girls on this question.

Table 5. Engineering Attitudes Survey: Tests for Gender Differences

Question	Within-Group Differences (Pre vs. Post)						Male/Female Differences	
	Female (N=348)			Male (N=330)			PRE	POST
	Pre Mean	Post Mean	p=	Pre Mean	Post Mean	p=	p=	p=
Scale: REAL LIFE[2]	1.59	1.00	**.000**	1.43	1.25	.288	.314	.192
Scale: CAUSE PROBLEMS[2]	2.20	2.20	.956	2.53	2.45	.602	.121	.191
Scale: JOBS[5]	34.98	35.91	.151	37.29	38.41	**.043**	**.003**	**.001**
Jobs Factor 1: INVENT[3]	4.76	4.64	.371	6.32	6.60	.075	**.000**	**.000**
Jobs F2: HELP SOCIETY[3]	6.70	6.69	.986	5.91	6.11	.325	**.002**	**.025**
Jobs F3: FIGURE THINGS OUT[4]	9.88	9.90	.973	10.51	10.43	.328	**.005**	**.030**
Jobs F4: MAKE LIVES BETTER[2]	5.70	5.86	.124	5.99	6.22	.062	**.010**	**.012**
Jobs F5: I KNOW ABOUT JOBS[2]	5.05	5.71	**.000**	5.28	5.59	**.023**	**.036**	.463
I'D ENJOY BEING A SCIENTIST[1]	1.70	1.61	.205	1.62	1.57	.521	.323	.640
I'D ENJOY BEING AN ENGINEER[1]	1.20	1.51	**.000**	1.66	1.88	**.003**	**.000**	**.000**

[1]Scale range: 0-4. [2]Scale range: 0-8. [3]Scale range: 0-12. [4]Scale range: 0-16. [5]Scale range: 0-64

Figure 3. Engineering Attitudes Survey: Tests for Gender Differences

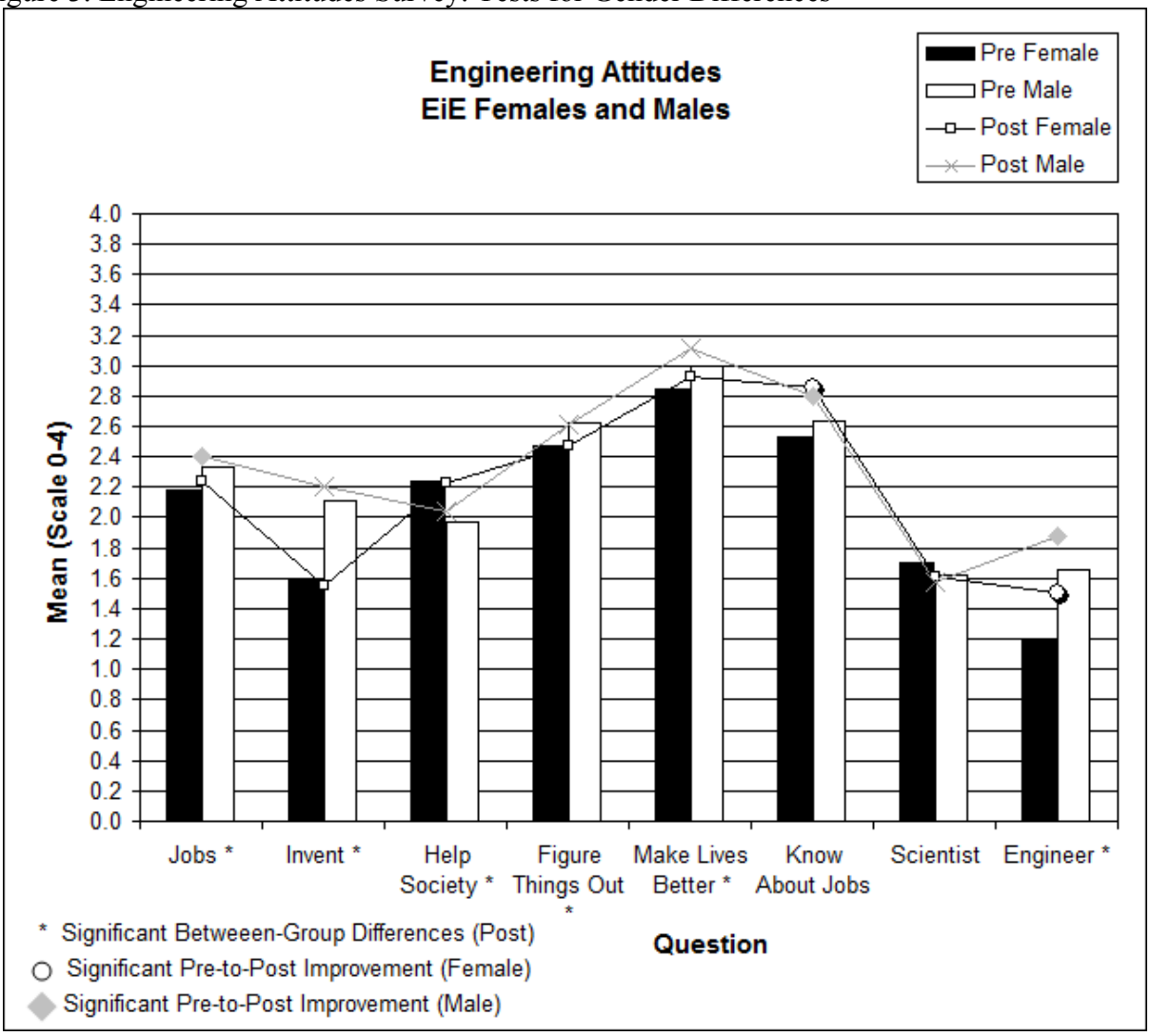


Table 6 and Figure 4 compare the responses of students who receive free or reduced-price lunch (FRL) with those who do not (N-FRL), for the EiE Test population only. All students were significantly more likely to agree that they would enjoy being an engineer on the post-survey than on the pre-survey (ENGINEER N-FRL p<.001, FRL p<.01). All students were also significantly more likely to indicate that they knew about what scientists and engineers do for their jobs (KNOW ABOUT JOBS N-FRL p<.001, FRL p<.01).

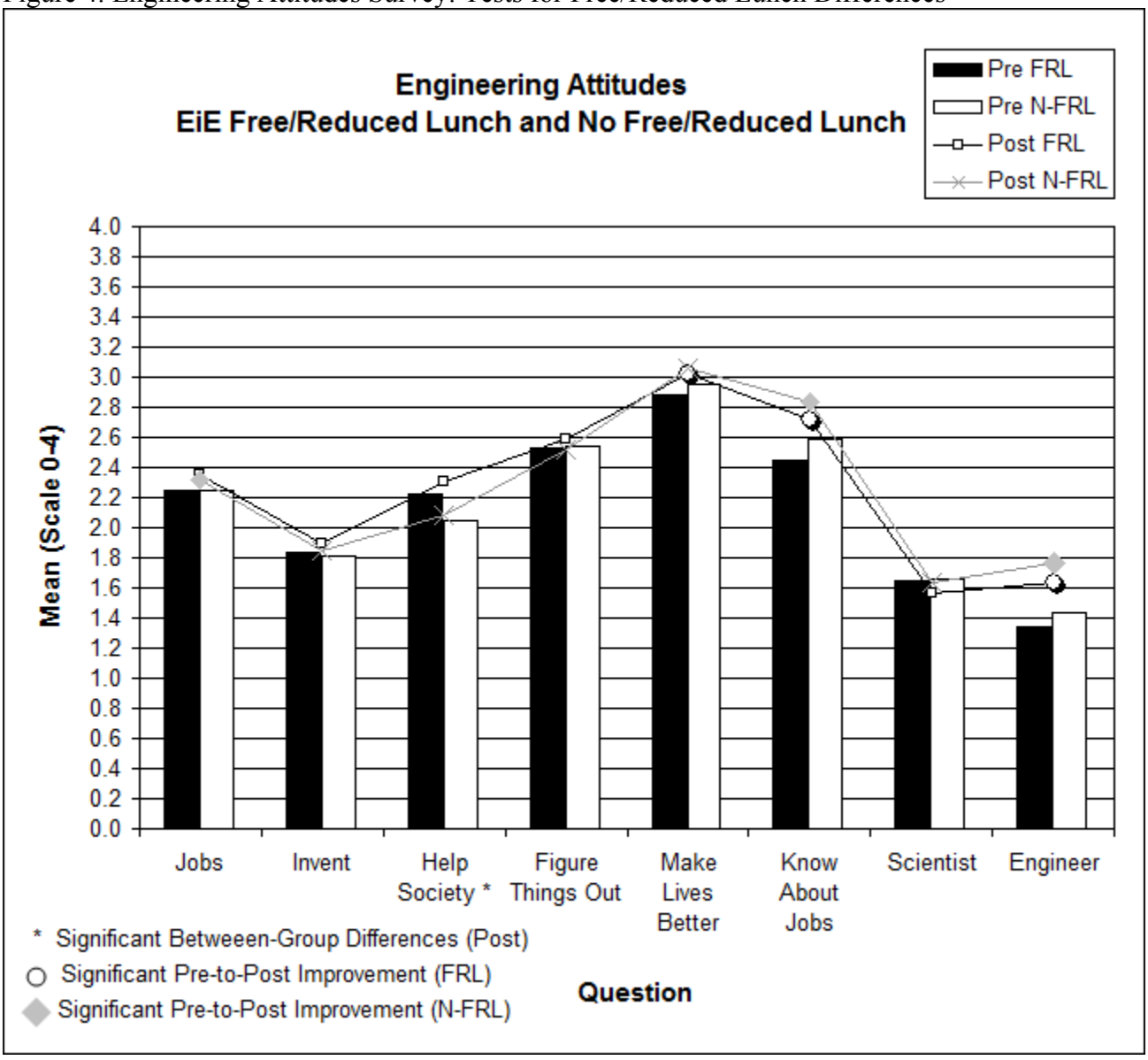
There were only four significant differences between the FRL and N-FRL groups. N-FRL students were significantly less likely to agree that science and math have nothing to do with real life (REAL LIFE p<.01); the mean for this item also decreased for FRL students, but not significantly. A second difference was on the JOBS scale, which is a super-scale comprising 16 of the 20 items on the survey: both group means increased overall, showing an increase in comfort with and interest in engineering and science jobs, but only the N-FRL increase was significant (JOBS p<.05). The FRL p-value, however, is close to significant, and the mean change is nearly as large.

Table 1. Engineering Attitudes Survey: Tests for Free/Reduced-Price Lunch Differences

Question	Within-Group Differences (Pre vs. Post)						FRL/ N-FRL Differences	
	N-FRL (N=409)			FRL (N=190)			PRE	POST
	Pre Mean	Post Mean	p=	Pre Mean	Post Mean	p=	p=	p=
Scale: REAL LIFE[2]	1.38	1.02	**.005**	1.73	1.44	.114	.076	**.032**
Scale: CAUSE PROBLEMS[2]	2.27	2.26	.914	2.26	2.41	.322	.736	.566
Scale: JOBS[5]	35.90	37.03	**.011**	35.96	37.65	.094	.971	.344
Jobs Factor 1: INVENT[3]	5.43	5.54	.544	5.50	5.68	.397	.715	.542
Jobs F2: HELP SOCIETY[3]	6.13	6.24	.397	6.67	6.93	.403	.071	**.008**
Jobs F3: FIGURE THINGS OUT[4]	10.16	10.07	.401	10.13	10.34	.794	.874	.307
Jobs F4: MAKE LIVES BETTER[2]	5.91	6.11	.050	5.77	6.05	**.041**	.356	.840
Jobs F5: I KNOW ABOUT JOBS[2]	5.18	5.68	**.000**	4.90	5.43	**.017**	.216	.205
I'D ENJOY BEING A SCIENTIST[1]	1.66	1.63	.800	1.65	1.57	.318	.935	.453
I'D ENJOY BEING AN ENGINEER[1]	1.44	1.76	**.000**	1.34	1.64	**.004**	.286	.285

[1]Scale range: 0-4. [2]Scale range: 0-8. [3]Scale range: 0-12. [4]Scale range: 0-16. [5]Scale range: 0-64

Figure 4. Engineering Attitudes Survey: Tests for Free/Reduced Lunch Differences



A third difference between the two groups can be seen on the scale of items relating to jobs to help people or society. FRL students scored a significantly higher mean on this item on the post-assessment, showing greater interest in such jobs (HELP SOCIETY $p<.01$). Finally, though both groups' means increased, only FRL students were significantly more likely on the post-survey to say that scientists and engineers make people's lives better (MAKE LIVES BETTER $p<.05$).

Summary

Students who completed the Engineering is Elementary curriculum showed some changes in their attitudes toward engineering than students control students. EiE children 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.

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. 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.

The primary goals of the Engineering is Elementary curriculum are to expose all children to engineering concepts, introduce them to the role of engineering in the world in which they life, and strengthen their problem solving and inquiry skills. After engaging with engineering challenges and activities, not surprisingly children's perceptions about their abilities related to engineering jobs and skills rise. Ideally, the increases in these attitudes can be maintained and fostered through middle school and high school grades to help create a more informed citizenry and perhaps a few more engineers.

Bibliography

1. Gibbons, S.J., Hirsch, L.S., Kimmel, H., Rockland, R., & Bloom, J. (2004). Middle school students' attitudes to and knowledge about engineering. Paper presented at ICEE Conference 2004, Gainesville, FL