Youth Perceptions of Science, Technology, and Engineering in Workshops at a Community Organization

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Abstract

As part of a graduate course for supporting K-12 teachers' use of technology in science, technology, engineering and mathematics (STEM) subjects, teachers worked in teams of 3 to 6 to create workshops for youth (in grades two to eight) at a community organization. Teachers used curriculum kits from the Engineering is Elementary (EiE) project of the Museum of Science, Boston, together with technological resources including iPads, to plan and conduct workshops with four sessions of eight hours each. A survey-based evaluation of 36 youth was conducted, examining their perceptions of science and engineering. An analysis of surveys, done before and after the workshops, showed statistically significant changes on some questions. For example, after the workshops, boys and girls more strongly agreed with an engineering-related survey question, that they liked thinking of new and better ways of doing things. Also after the workshops, boys and girls also agreed more strongly that they knew what scientists did for their jobs. In addition, after the workshops, girls more strongly agreed they knew what engineers did for their jobs, reaching a similar level as boys, whose responses did not change significantly. Overall, this case study suggests benefits of the program to participating youth.

Keywords: informal learning; science education; engineering education; STEM education; teacher professional development; engineering design process; curriculum; afterschool programs; elementary school; middle school; educational technology.

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Introduction

This research study is part of a project with complementary goals related to both developing teachers and serving youth from diverse communities. As part of a course for supporting teachers' use of technology in Science, Technology, Engineering, and Mathematics (STEM) subjects, pre-service and in-service teachers developed and implemented STEM workshops, with particular emphasis on engineering tasks, for student participants at a youth organization. Teachers used curriculum kits from the Engineering is Elementary project of the Museum of Science, Boston (Cunningham, 2009) as the primary basis of their workshops. They were also provided iPad minis and encouraged to find ways to support the curriculum using them. We have observed benefits to teachers from the approach, including gaining experience with teaching lessons with an engineering component. In particular, in previous research (Adams, Bernal, Cole-Jackson, & Martin-Hansen, 2015; Adams & Bernal, 2016), we found that teachers participating in the program showed gains in developing their Technological, Pedagogical, and Content Knowledge (Schmidt, Baran, Thompson, Mishra, & Koehler, 2009). We hoped that in addition to providing a learning experience for teachers, the program would also benefit the youth. With explicit, engaging instruction in science at informal science settings, gains can be made in science knowledge as well as attitudes about science (Brossard, Lewenstein, & Bonney, 2005). Informal science programs may help to stimulate participants' interests in science and enhance their views of science-related career options (Bell, Lewenstein, Feder and Shouse, 2009).

This work represents a case study of the particular combination of elements in this program, with curriculum units from the EiE project as a central element. The program also had some interesting characteristics as a case. Teachers had not worked with one another before. They had varying degrees of experience in STEM, but each teacher team was composed to have at least one participant with relatively greater experience in a STEM content area. Only one teacher had prior experience using curriculum kits from the Engineering is Elementary project. As will be discussed further, they had varying degrees of prior teaching experience. Although the program included iPads, these were not the central focus of this study. For example, the study did not seek to compare versions of the program with and without iPads.

This study is an initial investigation of youths' experiences of the program. The study explores overall impacts, focussing on the youth participants' perceptions of STEM and STEM careers before and after the workshops. In particular, it examines the questions:

1. Do youth attitudes about STEM change after participation in the workshops? Are there differences by gender?
2. Do the perceptions of youth regarding careers in STEM change after participation in the workshops? Are there differences by gender?

Design

Overall Design

As part of a 3-unit graduate level university course, twenty-two teachers developed STEM workshops that used curriculum guides from the Engineering is Elementary (EiE) project of the Museum of Science, Boston (www.eie.org). The average number of years of teaching experience was 6.5 years. Of this group, 26% had zero to two years of prior teaching experience, 35% had three to eight years of prior teaching experience, and 39% and nine to fifteen years of teaching experience. Approximately 25% of the group were in an M.A. program in educational technology, 25% were in an M.A. program in educational administration, 10% were in an M.A. in science education, 10% were in an MA in Curriculum and Instruction, and 5% were in an M.A. in mathematics education. The remaining 25% were not currently in a graduate option, but had completed an M.A., divided among educational technology, educational administration, or science education.

Five groups were formed of three to six teachers, and each group selected an EiE curriculum kit to use as a starting point. (A sixth group, which piloted a curriculum based on robotics that was not part of the EiE curriculum, was excluded from analysis.) Teachers were provided with a set of 10 iPad minis and encouraged to integrate them into the workshops in ways that supported instructional goals. One common use was as video recording devices to document steps of students' designs. Other uses included showing videos from the Internet related to the unit, as a way to record numeric data, as a tool to assist with a measurement, or as a tool for creating a retrospective presentation about the project.

The EiE project offers two collections of kits especially designed for use in out-of-school-time settings: the "Engineering Everywhere" series, for grades six to eight, and the "Engineering Adventures" series, designed for grades three to five. The teachers selected the following kits from these series:

- "Hop to It: Safe Removal of an Invasive Species" *http://www.eie.org/engineering-adventures/curriculum-units/hop-it*
- "Food for thought: Engineering Ice Cream" *http://www.eie.org/engineering-everywhere/curriculum-units/food-thought*
- "Put a Lid on it: Engineering Safety Helmets" *http://www.eie.org/engineering-everywhere/curriculum-units/put-lid-it-0*
- "Go Green: Engineering Recycled Racers"

http://www.eie.org/engineering-adventures/curriculum-units/go-green

Each kit was used by one group, except for the last kit, which was used by two groups. The selected kits spanned a range of engineering topics. However, like all kits from the Engineering is Elementary project, they included common structure. In particular, this includes the project's formulation of an Engineering Design Process with five elements: Ask, Imagine, Plan, Create, Improve (Cunningham, 2009). The process is a cyclical one, as shown by Figure 1.

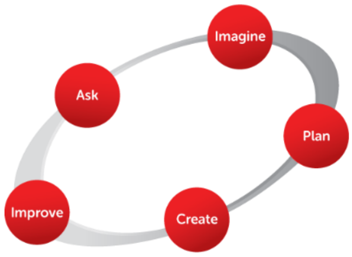

Figure 1: The EiE Engineering Design Process
Source: http://www.eie.org/overview/engineering-design-process

Altogether, these teams created five 8-hour workshops that involved four sessions of two hours each. Grant support funded both the costs of instruction for the teachers and the costs of the curriculum materials. The STEM workshops were offered at no cost to the participating youth. The present analysis is based on questionnaires. Additional analyses are underway using focus groups.

Participants

Fifty-nine students aged 8-13 participated regularly in the STEM workshops. Of these, 36 students, or 61%, provided consent forms to participate in the study. They self-identified as 56% female and 42% male, with 2% declining to state. Also, they self-identified as 47% African-American, 33% Hispanic / Latino, 3% Asian, and 17% as other / Caucasian / mixed ethnicity. Of the participants, 69% reported they were only offered the opportunity to do science projects or experiments in school once a month or less.

Surveys

Questionnaires with 10 items were administered at two points in time, immediately before and immediately after the workshops. The items used a 5-point Likert scale. Eight items were common to both questionnaires, and two items were unique to each. Appendix 1 provides a listing. Of the items common to both surveys, three came from a prior youth engineering and science attitudes assessment (Engineering is Elementary, 2010) with questions that were derived from a study of engineering attitudes and knowledge (Gibbons, Hirsch, Kimmel, Rockland, & Bloom, 2004). Four questions of the survey came from the *Trends in International Mathematics and Science Study Student 4th Grade Questionnaire* (NCES, 2011). An eighth question, concerning technology, was new. As descriptive information, the pre-assessment included two items concerning students' work ethic that came from an instrument concerning "grit" created by Duckworth, Peterson, Matthews, & Kelly (2007). These items, which are not designed for use in testing before and after an intervention, were not included on the post-assessment. The post-assessment also included two questions concerning overall learning in the STEM workshops that were not on the pre-assessment. Focus groups were conducted after the workshops and are being analysed in subsequent work.

Analysis and Results

Analysis

The responses to the Likert survey questions were coded on a scale of 1-5, with a higher number indicating stronger agreement. For example, "strongly disagree," was coded as a "1," "not sure" was coded as a "3," and "strongly agree" was coded as "5." Summations were completed of the demographic data along with survey questions that were unique to the pre and post surveys. Also, for this latter group of questions, data were disaggregated to compare responses of boys and girls. For questions that appeared on both the pre-and post-surveys, paired *t* tests were completed with an alpha of 0.05. Effect sizes were computed using Cohen's *d* and reported with the convention small ≥ .20, medium ≥ .50, large ≥ .80 (Cohen, 1992).

Descriptive Data Related to "Grit" Questions

Girls more strongly agreed with questions on the pre-assessment related to grit than did boys. On the question, "I am a hard worker," the mean response of boys was 3.3. On the other hand, the mean response of girls was 4.2, or slightly over "agree." A two-sample t-test found this difference was significant ($p < .05$). Similarly, on the question, "I am hard working and careful," the mean response was 3.3 for boys, but higher for girls, whose mean response was 4.4. A two-sample t-test was likewise significant for this question ($p < .001$).

Survey Results-Questions with Significant Changes

We first discuss results of the survey questions which provided a key source of information for the first two research questions:

1. Do youth attitudes about STEM change after participation in the workshops? Are there differences by gender?
2. Do the perceptions of youth regarding careers in STEM change after participation in the workshops? Are there differences by gender?

Table 1 presents a summary of data for which statistically significant changes were found.

Table 1:
Comparison of Youth Responses about Engineering and STEM Careers Before and After Workshops on Questions That Had Did Have Significant Changes (n= 36)

Question	Group	Mean Before	Mean After	N	Paired t-Test *p*-value	Cohen's *d*	Cohen's *d* description
I like thinking of new and better ways of doing things.[1]	All	3.94	4.46	35	0.02	0.52	medium
	Boys	3.73	4.40	15	0.14	0.53	medium
	Girls	4.21	4.47	19	0.14	0.40	small
I think I know what engineers do for their jobs.[1]	All	3.83	4.11	36	0.12	0.27	small
	Boys	4.27	4.13	15	0.58	-0.14	--
	Girls	3.60	4.15	20	0.03	0.53	medium
I think I know what scientists do for their jobs .[1]	All	3.75	4.17	36	0.04	0.38	small
	Boys	4.00	4.40	15	0.14	0.40	small
	Girls	3.50	3.95	20	0.14	0.39	small
Science is harder for me than for many of my classmates.[2]	All	2.92	2.72	36	0.38	-0.13	---
	Boys	3.53	2.87	15	0.01	-0.44	small
	Girls	2.55	2.65	20	0.77	0.07	--
Math is harder for me than for many of my classmates.[2]	All	2.14	2.75	36	0.02	0.40	small
	Boys	2.27	2.93	15	0.13	0.39	small
	Girls	2.10	2.70	20	0.08	0.42	small

[1]Source of item: Engineering is Elementary, 2010
[2]Source of item: NCES, 2011

As discussed in the subsequent sections, of two items specifically related to engineering (Engineering is Elementary, 2010), statistically significant changes were found for all students on one item, and for girls only on another item.

"I like thinking of new and better ways of doing things"

Mean responses to the question, "I like thinking of new and better ways of doing things," were 3.94 before the workshops, rising to 4.46 after the workshops, a significant increase ($p < .02$) and a medium effect size ($d = 0.52$).

"I think I know what engineers do for their jobs"

There were not statistically significant changes overall to the question, "I think I know what engineers do for their jobs," at least when the responses of boys and girls were combined. Before the workshop, the mean response was 3.83, and was 4.12 after the workshop, which was not a significant increase ($p = .12$), but yielded a small effect size ($d = 0.27$). However, the responses for this question differed when data for boys and girls were disaggregated. For boys, the mean response was 4.13 before the workshops and 4.06 after the workshops, a difference that was not significant ($p = 0.79$) and a negligible effect size ($d = -.06$). However, for girls, the mean response was 3.60 before the workshops and 4.15 after the workshops, a significant increase ($p < .03$) and a medium effect size ($d = .53$). Statistically significant changes were found on two science-related questions, as discussed in the next two sections.

"Science is harder for me than for many of my classmates"

In this particular question, responses did not change significantly for boys and girls combined. The responses of girls were 2.55 before the workshops, and 2.65 after the workshops, a change that was not significant ($p = .77$). On the other hand, there was a change for boys. The mean response for boys was 3.53 before the workshops, but 2.87 after the workshops, a significant decrease ($p < .01$) and a small effect size ($d = -0.44$). In other words, after the workshops, boys agreed less strongly with the statement.

"Math is harder for me than for many of my classmates"

Overall, participants disagreed with the statement from the TIMMS survey, "Math is harder for me than for many of my classmates" (NCES, 2011). Accordingly, mean responses for both boys and girls were under "3" before and after the workshops. An unanticipated outcome was that youth more strongly agreed with the negative statement after the workshops. The mean response was 2.14 before the workshops, but 2.75 after the workshops, a significant decrease ($p < .02$) and a small effect size ($d = 0.40$). These changes were unexpected given that math was not emphasized in the workshops. We now turn to discussing three further questions--questions for which no significant changes were found comparing responses before and after the workshops.

Survey Results-Questions without Significant Changes

On the three further questions, comparing responses before and after the workshops, we did not find the statistically significant changes. Table 2 presents a summary of youth responses. Two of these questions came from the TIMSS survey (NCES, 2011): "I enjoy learning science" and "I enjoy learning math." A third question that our team added as a modification did not change significantly, "I like using technology."

Table 2:
Engineering and STEM Attitudes Survey: Comparison of Youth Responses about Engineering and STEM Careers Before and After Workshops on Questions That Did Not Have Significant Changes (n= 36)

Question	Group	Mean Before	Mean After	N	Paired *t*-Test *p*-value	Cohen's *d*	Cohen's *d* description
I enjoy learning science.[2]	All	4.11	3.75	36	0.11	-0.31	small
	Boys	4.00	4.13	15	0.55	0.11	--
	Girls	4.15	3.45	20	0.06	-0.60	medium
I enjoy learning math.[2]	All	4.25	4.11	36	0.54	-0.12	--
	Boys	4.47	3.93	15	0.07	-0.40	small
	Girls	4.05	4.20	20	0.66	0.15	--
I like using technology.	All	4.46	4.71	35	0.18	0.27	small
	Boys	4.14	4.50	14	0.40	0.27	small
	Girls	4.75	4.85	20	0.49	0.19	--

[2]Source of item: NCES, 2011

Post-Assessment Survey Questions about the workshops

The post-assessment included a survey question that asked students to indicate their level of agreement with the statement, "I would be interested to take another workshop like the one I just took but on a different topic." The percentage of students agreeing with this statement was 50%, while 39% were neutral and 11% disagreed. The post-assessment also included an item that simply asked students to indicate their agreement with the statement, "I learned about engineering in the workshop." On this item, 92% of the students agreed, 3% were neutral, and 6% disagreed (the sum of the percentages exceeds 100% due to rounding).

Discussion and Conclusion

As discussed earlier, this case study used EiE project curricula, but in a way different from traditional, in-school implementations. It incorporated EiE materials targeted specifically for out-of-school-time settings that came from the "Engineering Adventures" and "Engineering Everywhere" series. Teachers of differing backgrounds, who had not worked together before, worked in teams to plan and conduct the workshops. They were allowed to make modifications to the EiE lessons, and they additionally incorporated technological resources. As mentioned in the previous section on participants, youth taking part in the study were predominantly from less-served populations. Of these youth, 69% indicated they had opportunities for doing science projects once per month or less, and 80% identified as either African American or Hispanic / Latino. With these conditions, on several survey questions, there were changes suggestive of learning about engineering processes and to some extent, engineering and science professions. Survey questions indicated that after the STEM workshops:

- boys and girls more strongly agreed that they like thinking of new and better ways of doing things
- boys and girls more strongly agreed that they knew what scientists did for their jobs
- girls more strongly agreed they knew what engineers do for their jobs
- boys less strongly agreed that science is harder for them than for many of their classmates.

In particular, we note that participation in the STEM workshops tended to equalize responses for boys and girls, both on the question about what engineers do for their jobs (which girls more strongly agreed with after the workshops, becoming more similar to responses of boys) and on the question about science being harder than for classmates (which boys less strongly agreed with after the workshops, becoming more similar to the responses of girls). As noted previously, before the workshops, and in comparison to girls, boys not only were more likely to report that science was harder for them, but also reported a lower self-perceived work ethic. Further work could more specifically explore any connections between these views in relation to participation in engineering activities. Responses to a survey question about math, *"*Math is harder for me than for many of my classmates*"* were unexpected in that students rated this comment more negatively at the end of the workshops.

Limitations and Recommendations for Future Work. There were several limitations to the findings that could be addressed in further research. While this initial study did not include a control group, further studies could include one. Although formal training in the EiE unit was not included in the program, it could be included in future projects like this. We note that it is likely that many afterschool program personnel may not have had access to formal training in implementing EiE curricula. The conditions of the present study were one example of a realistic situation. Our questionnaires rely on self-reports, which have limitations and are subject to reference bias (Duckworth & Yeager, 2015). Also at this initial stage, we had limited opportunities for data collection and wished to keep the surveys brief while exploring a range of topics. Further studies could include multiple question items on a narrower set of topics. In future iterations, it may be beneficial to drop questions not common to both pre- and post-assessments or to reword questions used as a post-assessment in a generic way so they could be used in the pre-assessment. In our pre-assessment survey, boys less strongly agreed with prompts related to "grit" than did girls, prompts such as "I am a hard worker." Further work could specifically explore connections between constructs related to grit and students' work in the Engineering Design Process, which specifically encourages learning from failures.

Final Thoughts. EiE curricula were developed initially for use in elementary school settings, and have been studied most extensively in a school context (Engineering is Elementary, 2014; Lottero-Perdue & Parry, 2016; Oh, Lachapelle, Shams, Hertel, & Cunningham, 2016). The project subsequently branched out to develop kits for use in out-of-school-time settings via the Engineering is Everywhere and Engineering Adventures series that were used in the current study. This study contributes to the base of research in uses of these curricula in out-of-school settings (Higgins, Hertel, Shams, Lachapelle, & Cunningham, 2015; Higgins, Hertel, Lachapelle, & Cunningham, 2013; Higgins, San Antonio, DiIeso, Meyer, Shams, Tauer, Lachapelle, & Cunningham, 2015; Higgins, San Antonio, Hertel, Cunningham, & Lachapelle, 2013). The model we report on embeds EiE materials in the context of a course for teachers, with field experience at a community organization. The research findings contribute to teacher development, and also to science and engineering education for diverse learners in an informal setting. The study suggests benefits to youth from participating in the program.

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