

Elementary Teachers' Changing Ideas about STEM and STEM Pedagogy through Interaction with a Pedagogically-Supportive STEM Curriculum

ABSTRACT

Every year, a cadre of elementary school teachers from across the country—some new to using the *Engineering is Elementary* engineering curriculum, some with a year or more of experience—participate in field testing of new engineering curriculum units. Our units are designed as supplementary materials and lessons that teachers can use in conjunction with their existing science curriculum to introduce children to key concepts and skills in engineering and technology through hands-on activities, integrating the STEM disciplines. We provide professional development to teachers each year to introduce them to our project, STEM teaching, and the newest engineering units that they will field test. This paper will present results from an analysis of our “STEM Questionnaire”, given to teachers before they participate in field testing and at the end of each field test year, asking teachers to explain what they think engineering and technology are, what engineering and technology activities they engage in with their classes, and what kinds of pedagogical practices they engage in.

Key Words: Elementary Education, Engineering Education, Project-Based Learning, Science Pedagogy.

AUTHOR BIBLIOGRAPHIES

Dr. Christine Cunningham is a Vice President at the Museum of Science, Boston where she oversees curricular materials development, teacher professional development, and research and evaluation efforts related to K-16 engineering and science learning and teaching. Her projects focus on making engineering and science more relevant, understandable, and accessible to everyone, especially marginalized populations such as women, underrepresented minorities, people from low socio-economic backgrounds, and people with disabilities. Dr. Cunningham's projects span the elementary to college educational continuum. Principal among these is Engineering is Elementary (EiE), a program she founded in 2003 and currently directs. EiE is creating a research-driven, standards-based, and classroom-tested curriculum that integrates engineering and technology concepts and skills with elementary science topics.

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THEORETICAL FRAMEWORK

The teacher guides we design for our engineering curriculum units are designed to support teachers in implementing new pedagogical styles and learning environments. Activities and lessons are designed to be usable within most typical formal public school elementary classrooms. Like their students, teachers learn through situated practice (Bruner, 2004; Lave & Wenger, 1991); our project models the pedagogical practices we espouse through hands-on activities and reflection on practice in professional development workshops, and through step-by-step guides, models of good questioning, and tips in teacher guides.

In addition, we believe that any new curriculum designed for use in schools must take into account the wider political, social, cultural, and historical context of classroom teaching and learning (Roth & Lee, 2007). Our engineering units are designed for usability within a typical classroom by a typical teacher. Knowing that teachers must negotiate contradictions such as the need to cover more content and lack of time, the need to meet standards and to engage students' interest, the engineering units are designed to mediate these contradictions through connections and compromise, and above all, careful design to constraints.

Since teachers have their own ideas about and sense of what makes good teaching, curriculum units must be designed to support teachers and inspire them as they gradually implement pedagogical practices that afford inquiry learning, open-ended design, and the development of active learning communities in the classroom (Ball & Cohen, 1996; Davis & Krajcik, 2005). These are the kinds of learning environments that engage students productively in the social and epistemic practices of STEM disciplines and enable deep learning (Duschl, 2008; Duschl & Grandy, 2007; Engle & Conant, 2002; Rosebery, Warren & Conant 1992).

LITERATURE REVIEW

Little is known about elementary school teachers' conceptions of engineering and technology, and how they may change with professional development. A pilot study of Massachusetts' teachers ideas about engineering and technology found that teachers' ideas are overly broad and do not conform to standards-based definitions (Cunningham, Lachapelle, and Lindgren-Streicher, 2006). The American Association for the Advancement of Science (AAAS, 1993) and the International Technology and Engineering Educators Association (ITEEA, 2000) both define technology as something that humans do to modify the natural world to satisfy human needs and wants. As ITEEA defines it in their *Standards for Technological Literacy* (2000), Technology is "the innovation, change, or modification of the natural environment to satisfy perceived human needs and wants." This is a complex definition, which may leave teachers prone to confusion, particularly when they think about the intersection of technology and art (Cunningham, Lachapelle, and Lindgren-Streicher, 2006).

The introduction of a new curriculum may or may not lead to changes in teachers' STEM conceptions or their pedagogy. The curriculum as enacted by teachers can be different—sometimes very different—from the curriculum as it was written by developers (Stein et al., 2007). The way that teachers enact curriculum is largely dependent upon their understanding of and beliefs about how subject-matter should be taught (Cohen, 1990; Jennings, 1996; Spillane,

1999). When curriculum materials are designed to support teacher learning of new pedagogy and subject-matter, teachers are more likely to implement the curriculum with greater fidelity (Schneider & Krajcik, 2002).

A pilot study of 24 teachers completed by external evaluators for *Engineering is Elementary* found that training and participation in field testing significantly affected teachers' self-reported pedagogical practices. Field test teachers were more likely to report using problem-solving in science and math, as well as using engineering examples and concepts in their teaching, after participating in a field test, compared to their responses on the pre-survey (Carson & Campbell, 2007).

RESEARCH QUESTIONS

The purpose of this study is (1) to examine how teachers' ideas about engineering and technology change after participating in EiE professional development and the teaching of one or more EiE units; and (2) to examine how teachers' willingness to engage in open-ended pedagogical practices and engineering activities with their students change after participating in professional development and teaching at least one *Engineering is Elementary* engineering unit.

METHODOLOGICAL CONSIDERATIONS

Beginning with the 2008-2009 school year, we decided to try to learn more about the pedagogical practices of teachers using EiE in their classrooms. We are particularly interested in how their practices may change when teachers first learn about and begin to teach EiE. During the 2008-2009 and 2009-2010 school years, we collected data from teachers using the STEM survey, an instrument developed by Campbell & Kibler Associates (2007).

Participants

Most participants were elementary school teachers who had agreed to take part in field testing with the *Engineering is Elementary* program during the 2008-2009 and 2009-2010 school years. These participants included both field test and control teachers. During the 2009-2010 school year, EiE began two more grant-funded projects that included an evaluation component. EiE gathered data from teachers participating in these two projects, in addition to field test and control teachers, via the STEM survey. The Bechtel National Dissemination through Regional Partners (NDRP) Project introduced EiE through regional partners in seven states (Kentucky, Maryland, New York, North Carolina, Oregon, Vermont, and Wisconsin). Through the Cargill Minnesota project, the Science Museum of Minnesota introduced EiE to teachers in two districts in Minnesota.

Engineering is Elementary curriculum units are each developed on a 2.5-3 year cycle. During the first school year, units are developed from scratch and pilot tested in local classrooms, where they are observed by staff who aid with implementation and engage on-the-fly hypothesis testing and revision. Field testing occurs during the second school year of development of a new engineering unit, after it has been piloted and revised. Each year, twelve elementary school teachers (grades 1-5) are recruited from each of five U. S. states by field site leaders local to their

states to implement the field test versions of the new curriculum units. Professional development for these teachers is provided by the state-based field site leaders. Because our engineering units are designed to be taught in conjunction with a related science topic, field test teachers are required to teach the related science unit in addition to the engineering unit being field tested. Final (or near-final) revisions of the curriculum units are based largely on field test teachers' feedback.

Field test teachers receive curriculum materials (including student storybooks, a teacher guide, and a materials kit for hands-on activities), professional development in engineering teaching, and a stipend for their participation. During the 2008-2009 school year, an additional twelve teachers per state, who taught the same (engineering unit-related) science topics as field test teachers, were recruited by field site leaders to participate in the evaluation as control teachers. These teachers were offered the same compensation as the field test teachers, to be delivered after their participation in control testing was complete. Control teachers completed the same surveys and collected the same data as field teachers, but were required only to teach the related science unit for an EiE unit, not the EiE unit itself.

Teachers for the NDRP project, like field test teachers, were recruited by NDRP regional partners local to their states. These teachers were required to complete similar data collection and teaching responsibilities as field test teachers, and received similar compensation. Twenty-four NDRP teachers were recruited in each of the seven NDRP states.

At the beginning of the 2008-2009 and 2009-2010 school years, teachers new to working with EiE—who had never before participated in professional development with our project, participated in a control or field test, or taught one of our engineering units—were asked to complete a “STEM Survey”. The STEM survey asks teachers to define engineering and technology, and to explain what kinds of activities they did with their students to teach engineering and technology. It also asks teachers to respond to a number of Likert-scale statements about their pedagogical practices. At the end of each field test year, all participating field test teachers and control teachers were asked to complete the same survey again, as a post-test.

Survey Instrument

The STEM survey consists of four open-ended questions (see Table 1 below), as well as twenty-three Likert-scale questions (Table 2). The pre-assessments were administered before the teachers attended any EiE workshops or events. The post-assessments were administered sometime during the school year, after a teacher had attended an EiE Professional Development workshop and taught one or more EiE units in her classroom.

Table 1: STEM Survey Open-Ended Questions

Question Text
How would you define engineering? (Please give us your own ideas, don't look up an answer)
What, if any, activities related to engineering do you do in your classes?
How would you define technology? (Please give us your own ideas, don't look up an answer)
What, if any, activities related to technology do you do in your classes?

Table 2: STEM Survey Likert-Scale Questions

Question Text
A. Students work together in pairs or small groups.
B. Students use calculators/computers.
C. Students collect data or information to analyze.
D. Students work on projects.
E. Students use things from everyday life in solving problems.
F. Students discuss their completed homework.
G. Students try to solve sample problems.
H. Students explain orally or in writing their problem solving strategies.
I. Students work on problems for which there is no immediately obvious method of solution.
J. Students explain how they solve complex problems.
K. Students solve the same problem using more than one method.
L. Students explain orally or in writing the rationale behind the problem solving strategies of other students.
M. I use practical or story problems related to everyday life.
N. I use the textbook.
O. I ask students what they know related to the topic being covered.
P. I describe engineering careers to my students.
Q. I talk about the courses and skills needed to go into engineering.
R. I use engineering examples in math lessons.
S. I use engineering examples in science lessons.
T. I use engineering examples in subject areas other than math and science.
U. I use an engineering design process in math lessons.
V. I use an engineering design process in science lessons.
W. I use an engineering design process in subject areas other than math and science.

Procedures: Open-Ended Analysis

Teacher responses to the open-ended questions on the STEM survey were entered into a Microsoft Access database. Codes for the teacher responses were then developed using grounded theory procedures (Strauss & Corbin, 1990). Both the “How would you define engineering?” and the “How would you define technology?” questions had more than a dozen possible codes. These two questions were coded by one researcher for the whole dataset. Fifty of the responses to each question were randomly selected and coded by a second researcher to compare reliability. After comparisons and adjudication, the two researchers decided to merge several of the codes and delete some that had low counts. After adjudication and recoding, the reliability for “How would you define engineering?” was .81. For “How would you define technology?” the reliability was .76. See Table 4 and Table 3 for the final lists of codes for each of these questions.

Table 3: Revised Codes for “How Would You Define Technology?”

Code	Code Description
-1	No answer given/missing
T0	Answer is incomprehensible / is not related to technology
T1	A solution to a problem
T2	Something invented / designed / created (includes “something engineered”)
T3	Something used by engineers / engineering
T4	Something man-made / created by humans
T5	It can be a process / system / method
T9	An idea
T15	Something used for learning (makes it easier / facilitates it)
T17	An improvement on (an already existing) technology
T33	Has to do with math and/or science
T80	Something that makes work or life easier / meets a need – includes earlier codes: T6: Something that makes work easier T7: Something that makes life easier / meets a human need or want T8: Something that improves a process / system T16: Something that increases productivity or efficiency T44: Something to help nature / animals / our environment T55: An adaptation of nature to solve human problems
T81	Various types of technologies – includes earlier codes: T10: Tools / machinery / devices T11: Computers T12: Communication systems (more than devices) T13: A list of more than one object or process as an example T14: Electronics / something that uses electricity

Table 4: Revised Codes for “How Would You Define Engineering?”

Code	Code Description
-1	No answer given / missing
E0	Answer is incomprehensible / is not related to engineering
E1	Problem solving / solutions to problems
E2	Designing / creating / inventing
E3	A process
E5	Engineers / engineering uses technology
E6	Engineers / engineering uses tools / machines
E7	Building / making things / constructing
E13	Making work and life better or easier; meeting human needs or wants
E18	Figuring out how things work
E21	The creation of processes or systems
E33	Has to do with math and/or science
E88	Improving things / processes – includes earlier codes: T4: Improving things / redesign T15: Improving processes / practices / systems T17: Making things more efficient
E89	Has to do with various named kinds of technology – includes earlier codes: T8: Tools / machines / mechanicals T9: Technologies T10: Computers T11: Communication systems T12: Bridges / buildings / structures

Once all of the open-ended responses were recorded and coded, and a conclusion had been reached about the various codes, we looked at the results in terms of the number of respondents who defined engineering and technology as relating to problem solving, machines and/or tools, science and math, and a general “helpfulness” with the day to day problems and desires of human beings.

The remaining two open-ended questions, asking about what activities teachers do in their classes, will not be discussed in this paper.

Procedures: Likert-Scale Analysis

All numerical results were exported to SPSS, along with teacher demographic information. All answers to the Likert scale items were first combined into a single score (All_Scale) to test for internal reliability and factorability by means of reliability analysis and principal component analysis (PCA) with direct oblimin rotation in PASW v17.0. We thought that question N “I use a textbook” (see Table 2) might be best reversed, since all the other questions had to do with increasing open-ended and problem-solving practices in the classroom, so the reversed version was used in the analysis. A scale made up of all pre-survey items had an internal reliability of Cronbach’s alpha = .901, and the same scale with all post-survey items (Treatment group teachers only, control excluded) had a reliability of Cronbach’s alpha = .878. Two items did not contribute to reliability on either the pre-survey or the post survey: question N and question O.

These questions were dropped from the scales. We call these resulting scales the Pre_All_Scale and the Post_All_Scale.

PCA with direct oblimin rotation of the items from the Pre_All_Scale showed that indicators of factorability were good (Bartlett's Test of Sphericity $p < .001$; KMO = .825). Four components were extracted with eigenvalues > 1.0 explaining 62.5% of the cumulative variance, and the scree plot showed a fairly sharp elbow with the bend at components 3 & 4. Inspection of the pattern matrix showed that all of the engineering implementation questions (P through W) formed a strong first component, with the other questions forming three components. A similar pattern held upon analysis of the Post_All_Scale (Bartlett's Test of Sphericity $p < .001$; KMO = .809); however 6 components were extracted accounting for 70.2% of the cumulative variance. Of these, the pattern matrix showed two components made composed of questions P through W, and questions A through M making up the other 4 components.

We decided, both because of the limited number of items and because of the variability in component composition within the two major subgroups, to divide the All_Scale into two parts: one comprised of the engineering implementation questions P-W (the Engineering_Scale) and one comprised of the remaining questions A-M (the Pedagogy_Scale). Internal reliability analysis showed the Engineering_Scale to be highly reliable (on the pre-survey: Cronbach's alpha = .931; on the post-survey: Cronbach's alpha = .919). The Pedagogy_Scale also showed good internal reliability (on the pre-survey: Cronbach's alpha = .841; on the post-survey: Cronbach's alpha = .815). PCA of the Pedagogy_Scale showed there was still possibility of factorability. For the Pre_Pedagogy_Scale (Bartlett's Test of Sphericity $p < .001$; KMO = .788) three factors were extracted explaining 58.3% of the cumulative variance; for the Post_Pedagogy_Scale (Bartlett's Test of Sphericity $p < .001$; KMO = .772) four factors were extracted explaining 62.5% of the cumulative variance. PCA of the Pre_Engineering_Scale (Bartlett's Test of Sphericity $p < .001$; KMO = .847) extracted only one component with eigenvalue > 1.0 (explaining 67.8% of the variance) and of the Post_Engineering_Scale (Bartlett's Test of Sphericity $p < .001$; KMO = .843) extracted two components explaining 77.1% of the cumulative variance. Again, we decided against continuing to break down either of these scales.

Inspection of the histograms and tests of normality showed that the Pedagogy_Scale was probably normally distributed (Kolmogorov-Smirnov Statistic=.080 $p = .200$ & Shapiro-Wilk=.986 $p = .597$ on the Pre; on the Post Kolmogorov-Smirnov=.074 $p = .200$ & Shapiro-Wilk=.984 $p = .499$). However, the Engineering_Scale was clearly not normally distributed (Kolmogorov-Smirnov Statistic=.127 $p = .005$ & Shapiro-Wilk=.916 $p < .001$ on the Pre; on the Post Kolmogorov-Smirnov=.125 $p = .006$ & Shapiro-Wilk=.959 $p = .018$), so we decided to run the Wilcoxon Signed Ranks non-parametric statistical test to check for significant differences on this scale from the pre- to the post-survey. For the Pedagogy_Scale, we used a t-test to measure differences between the paired pre- and post-surveys.

RESULTS

Open-Ended Questions

Table 5 shows the demographic distribution of respondents by state. Pre-surveys were administered before the teachers had attended any workshops and before they were given the materials to teach an EiE unit. EiE Post-surveys were collected from teachers after they completed both a workshop and the teaching of an EiE unit. Control post-surveys were collected from teachers who participated in field testing as controls. These teachers took the post-survey after they taught a science unit that corresponded to an EiE unit, but before participating in any EiE professional development or teaching. The total number of respondents to the STEM pre-survey for all sites is 302, there were 292 post-survey responses from EiE teachers, and 19 from control teachers. Since so few control teachers responded to the survey, their responses will not be included in the analysis—only EiE (treatment) post-surveys will be considered.

Table 5: Distribution of STEM Surveys by State and Treatment Type

State	Pre-Surveys	EiE (Treatment) Post-Surveys	Control Post-Surveys	Total
CA	61	22	10	93
CO	19	42	3	64
FL	17	14		31
KY	28			28
MA	26	93	4	123
MD		9		9
MN	66	54	2	122
NC	23	17		40
NH		3		3
NY	22	5		27
OR	21	10		31
VT	2	15		17
WI	17	8		25
Total	302	292	19	613

EiE had a large impact on teachers' views of technology and engineering. In their responses on the pre-survey, 16.5% of teachers indicated that technology is a solution to a problem (Code T1, see Table 6); however, after participating in EiE, 47.6% of teachers made this response. Teachers were 12.6% more likely on the post-survey to say that technology is something invented or designed (Code T2) than on the pre-survey, and 11.1% more likely to say that technology is something created by humans (Code T4). They were 39.4% less likely on the post-survey to define technology by naming a collection of technologies (Code T81).

Similarly, 22.2% more teachers were likely to say that engineering involves solving problems (Code E1) on the post-survey as on the pre-survey (Table 7). This was the second most likely coded response on both pre- (33.8%) and post-surveys (56.5%), after Code E2 (Designing / creating / inventing) (pre-60.1%; post-66.7%), which increased much less dramatically (+6.6%). Other major changes from pre- to post- include a greater likelihood (+22.7%) of saying that

engineering is a process (Code E3); more teachers saying that engineering is improving things and processes (Code E88: +19.0%); more teachers saying that engineering is a process (Code E3: +15.5%) or has to do with math and / or science (Code E33: +15.9%); and fewer teachers saying that engineering is building or constructing things (Code E7: -18.6%).

Teachers' qualitative responses to the "How would you define technology?" and "How would you define engineering?" open-ended questions suggest that, on the post-survey, teachers attend to a set of similar characteristics and traits when talking about these intertwined disciplines. In both questions, a large number of respondents identified these disciplines as solving problems. 49.5% of teachers said, on the post-survey, that technologies are solutions to problems (Code T1). Not surprisingly, given how EiE defines engineering and technology in professional development and curricular materials, 56.5% of participants indicated that engineering involves problem solving or solutions to problems (Code E1). Respondents said, for example, that they would define technology as:

"Almost anything that solves a problem or meets a need."

"Finding a way to solve a problem."

"Technology is anything that solves a problem. It can be anything from an eraser at the end of a pencil to a large piece of machinery."

Table 6: "How Would You Define Technology?" Percent Coded (Treatment Group Only)

Code	Technology Code Text	% (Pre)	% (Post)	Post - Pre
T0	Answer is unrelated or incomprehensible	1.9%	1.4%	-0.5%
T1	A solution to a problem	16.5%	49.5%	33.0%
T2	Something invented / designed / created	20.1%	32.7%	12.6%
T3	Something used by engineers / engineering	1.0%	1.1%	0.1%
T4	Something man-made / created by humans	4.9%	16.0%	11.1%
T5	Can be a process / system / method	5.8%	12.1%	6.3%
T9	An idea	1.3%	0.7%	-0.6%
T15	Something used for learning	6.5%	0.4%	-6.1%
T17	An improvement on an existing technology	0.6%	3.2%	2.6%
T33	Has to do with math and/or science	5.2%	3.2%	-2.0%
T80	Something that makes things easier / fills a need	48.2%	51.2%	3.0%
T81	Names various types of technologies	64.7%	25.3%	-39.4%
T10	→ Technologies: tools / machinery	38.5%	20.6%	-17.9%
T11	→ Technologies: computers	26.2%	5.0%	-21.2%
T14	→ Technologies: electronics	17.2%	0.7%	-16.5%

*Percentages >10.0% are bolded.

Table 7: "How Would You Define Engineering?" Percent Coded (Treatment Group Only)

Code	Engineering Code Text	% (Pre)	% (Post)	Post - Pre
E0	Answer is unrelated or incomprehensible	2.9%	0.0%	-2.9%
E1	Problem solving / solutions to problems	33.8%	56.5%	22.7%
E2	Designing / creating / inventing	60.1%	66.7%	6.6%
E3	A process	11.7%	27.2%	15.5%
E5	It uses technology	5.8%	8.7%	2.9%
E6	It uses tools / machines	1.9%	2.5%	0.6%
E7	Building / making things / constructing	29.5%	10.9%	-18.6%
E13	Makes work & life better / easier	16.6%	20.7%	4.1%
E18	Figuring out how things work	10.7%	0.7%	-10.0%
E21	The creation of processes or systems	4.2%	4.3%	0.1%
E33	Has to do with math and / or science	19.2%	35.1%	15.9%
E88	Improving things / processes	11.4%	30.4%	19.0%
E89	Has to do with various named kinds of technology	25.0%	26.1%	1.1%
E8	→ Technology: tools / machines / mechanics	10.4%	5.1%	-5.3%
E12	→ Technology: buildings / bridges /structures	11.0%	2.9%	-7.1%

*Percentages >10.0% are bolded.

Teachers defined engineering as:

“Solving problems by designing with knowledge of math and science.”

“Engineering is finding and improving a solution to a problem.”

“Engineering is problem solving. It is the design and creation of things and solutions.”

While many teachers noted that engineers solved problems, the most common response was that engineers designed, created, or invented (Code E2: pre-60.1%; post-66.7%). As one teacher said, “engineering is the art of planning, designing and creating to solve a problem or fill a need.” Other common verbs associated with engineering included building, constructing, or making things (Code E7: pre-29.5%), though this response became much less common on the post-survey (10.9%):

[Engineering is] “the study of building/constructing.”

“The manner in which something is built.”

“Engineering is working with sketches/drawings to build something that helps to solve a problem.”

Fortunately, many of the respondents also recognized that doing engineering involved using math or science, particularly on the post-survey (Code E33: pre-19.2%; post-35.1%):

“Engineering is using scientific, mathematical, and technical knowledge to design and implement materials for a specific purpose.”

[Engineering is] “the creative use of materials with an understanding of mathematics and science to design things for problem solving.”

Respondents shared some common views about the purposes of engineering and technologies. About half of all teachers (on both the pre- and the post-survey) responded that a technology was something that makes work or life easier (Code T80), and 16.6% on the pre-survey and 20.7% on the post-survey indicated that engineering involved making work or life easier (Code E13). As teachers told us:

“Technology is anything we use to make our life easier: microwave, TV, computer, lights, electricity, a pen, or a dish.”

“Technology is anything that helps us do things easier or quicker.”

“...It [engineering] makes the world around us easy to function in.”

“Engineering is the application of science and math to improve the human condition.”

When objects were specifically identified as technologies, teachers’ lists still included some of the perennial favorites, particularly on the pre-survey (Code T81: pre-64.7%; post-25.3%). Tools, machinery, mechanical devices, or equipment (Code T10: pre-38.5%; post-20.6%) were commonly mentioned as well as computers (Code T11: pre-26.2%; post-5.0%) or electronics (Code T14: pre-17.2%; post-0.7%). Engineers were often mentioned as the creators of the technologies, which were also called out in the engineering question as tools or machines (Code E8: pre-10.4%; post-5.1%), or bridges, buildings, or structures (Code E12: pre-11.0%; post-2.9%). As teachers told us on the pre-survey:

“Technology: the tools used to design.”

“Technology is the use of computers and other tools to complete work.”

“Technology involves using computerized equipment to interact, create models, communicate, organize, and sort information in an efficient manner.”

“Technology is any electronic creation used to aid humanity.”

“Technology is new and electronic.”

“Engineering is the study of structures and material strength.”

“Engineering is the development of buildings, bridges, etc. It begins with planning. And includes all the steps in the process until the structure is created.”

In the responses it became clear that some respondents believed that engineering not only improves work or life, but (particularly after participation in EiE) teachers also recognized that the process was applied reflexively, that is, that engineering may work to improve things or practices, process or systems (Code E88: pre-11.4%; post-30.4%).

[Engineering is] “looking at how machines work to improve or create new machines to make things more efficient.”

[Engineering is] “a profession that develops and improves technologies to solve a problem.”

It is interesting that more than a quarter of post-survey respondents stated that engineering involves a process (Code E3: pre-11.7%; post-27.2%); about 4% also said that engineering creates processes (Code E21). In keeping with this understanding, some teachers responded that a technology can be a process, system, or method (Code T5: pre-5.8%; post-12.1%) in addition to creating objects—especially on the post-survey:

“Engineering is a process for creating technology.”

[Engineering is] “using science/math/technology to create or improve a new product or process.”

[Technology is] “a process involving the creation of something to solve a problem.”

“Technology is any thing or process created by people to solve a problem.”

Likert Scales

The sample of teachers who completed both a pre- and a post-survey is unfortunately rather limited. The EiE (treatment) sample includes 86 teachers who completed both surveys, and the control includes only 16. Due to the very small control sample size, the control group is excluded from the current analysis.

Using a paired samples test, the difference between the pre- and the post- Pedagogy_Scales was found to be not significant. However, the difference between the pre- and the post- Engineering_Scales was found to be highly significant ($p < .001$) using a Wilcoxon Signed Ranks test (see Table 8). Looking at the questions individually with a Wilcoxon Signed Ranks test (see Table 9), we see that measurements of individual questions are consistent with the findings for scales: none of questions A-M increased significantly, while all of questions P-W increased significantly.

Table 8: Means and Standard Deviations for Scales: EiE (Treatment) Group

Scale	N	Mean (Pre-)	S.Dev. (Pre-)	Mean (Post-)	S.Dev. (Post-)	Statistic	P-value
Pedagogy_Scale (Questions A-M)	86	24.37	5.684	25.20	5.258	1.681 ¹	.096 ²
Engineering_Scale (Questions P-W)	84	5.87	5.254	9.42	5.371	-5.619 ³	.000

¹ Paired Samples Test t; ² 2-tailed; ³ Wilcoxon Signed Ranks Test Z

Table 9: Means and Standard Deviations for Likert-Scale Questions: EiE (Treatment) Group

Question Text	Mean (Pre-)	S.Dev. (Pre-)	Mean (Post-)	S.Dev. (Post-)	p-value*
A. Students work together in pairs or small groups.	2.36	.529	2.44	2.42	.542
B. Students use calculators/computers.	1.69	.619	1.73	1.71	.684
C. Students collect data or information to analyze.	1.71	.684	1.76	1.78	.658
D. Students work on projects.	1.88	.726	1.93	1.92	.636
E. Students use things from everyday life in solving problems.	1.93	.716	1.95	1.95	.766
F. Students discuss their completed homework.	1.86	.799	1.84	1.85	.847
G. Students try to solve sample problems.	2.19	.695	2.30	2.31	.724
H. Students explain orally or in writing their problem solving strategies.	2.17	.770	2.18	2.20	.717
I. Students work on problems for which there is no immediately obvious method of solution.	1.45	.835	1.57	1.58	.774
J. Students explain how they solve complex problems.	1.77	.777	1.87	1.85	.744
K. Students solve the same problem using more than one method.	1.79	.784	1.88	1.87	.682
L. Students explain orally or in writing the rationale behind the problem solving strategies of other students.	1.45	.877	1.56	1.57	.875
M. I use practical or story problems related to everyday life.	2.12	.726	2.16	2.19	.584
N. I use the textbook.	1.44	.862	2.06	.97	.888
O. I ask students what they know related to the topic being covered.	2.46	.609	2.52	2.53	.588
P. I describe engineering careers to my students.	.75	.742	1.38	.775	.000
Q. I talk about the courses and skills needed to go into engineering.	.63	.673	1.15	.752	.000
R. I use engineering examples in math lessons.	.73	.717	1.05	.743	.000
S. I use engineering examples in science lessons.	1.02	.836	1.50	.768	.000
T. I use engineering examples in subject areas other than math and science.	.63	.757	1.01	.843	.000
U. I use an engineering design process in math lessons.	.65	.814	1.06	.896	.000
V. I use an engineering design process in science lessons.	.92	.881	1.39	.892	.000
W. I use an engineering design process in subject areas other than math and science.	.54	.768	.87	.979	.002

*Wilcoxon Signed Ranks Test.

INTERPRETATION

Teachers' ideas about engineering and technology were closer to a standards-based definition on the post-survey than on the pre-survey, after participating in *Engineering is Elementary* professional development workshops and teaching at least one EiE unit. This suggests that teachers are learning more about engineering and technology from EiE, which introduces the standards-based definitions of these concepts. Before participating in EiE, teachers are more likely to define technology in terms of examples – particularly tools, machines, computers and electronics – and less likely to define technology as a solution to a problem, or something designed or invented. Also before participating in EiE, teachers are slightly more likely to identify engineering as building or constructing, and less likely to define it as problem solving, a process in itself, having to do with improving things and processes, and having to do with math and / or science.

The similarity in the types of responses offered by respondents for the technology and engineering open-ended questions on the post-survey suggests that many of them may be coming to understand the interconnected nature of these two terms. The analysis of the open-ended responses suggests that there is a need for elementary school teachers to become better acquainted with standards-based definitions of engineering and technology, and that professional development can meet that need.

We did not find that teachers change their science and math pedagogical practices after participating in EiE professional development and teaching; however we did find that teachers make greater use of engineering concepts and examples, including the engineering design process, across STEM subjects after participating in EiE.

We plan to do further work in future to quantify elementary school teachers' understanding of technology and engineering and how it changes after participation in EiE with a larger sample size and further analysis of the open-ended assessments. We anticipate that, as interest in STEM education grows, public interest in the STEM knowledge and pedagogical practices of elementary school teachers will increase.

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