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Two elementary schools' developing potential for sustainability of engineering education

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Abstract The Next Generation Science Standards present a way for engineering lessons to be formally integrated into elementary classrooms at a national level in the United States. Professional development programs are an important method for preparing teachers to enact the new engineering practices in their science classrooms. To better understand what contextual factors help a professional development program have a sustained effect on the implementation of engineering, we closely examined two elementary schools within the same school district that participated in the same professional development program but had very different outcomes in their lasting implementation of engineering. Using the case study method, we corroborate quantitative and qualitative sources of data measuring students' learning and attitudes; teachers' learning, attitudes, and implementation fidelity; perceived teacher community; and administrative support. Our analysis revealed that although the professional development program had district-level administrative support, there was considerable variation between schools in how teachers' perceived school level support. In addition, teachers at the sustaining school collaborated and co-taught with one another. Our findings support previous literature on the role of administrative support and teacher learning communities. We discuss practical ways that professional development

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programs can seek to foster a context which is supportive of sustaining curriculum change for engineering.

Keywords Elementary engineering · Teacher professional development · Teacher support

Introduction

Engineering as a content area in formal and informal K-12 education has been growing in importance and attention in the U.S. (National Research Council 2009). In particular, there is exciting potential for engineering to serve a role in enhancing students' understanding of mathematics and science (Macalalag et al. 2010; Mehalik et al. 2008). Well-designed engineering curricula incorporate science and mathematics, creating concrete connections between the subjects and reinforcing students' science and mathematics knowledge (Moore et al. 2014). This potential, in addition to other student learning benefits, has increased the level of value that some states have placed on integrating engineering into formal K-12 education. Massachusetts was a leader in adopting engineering standards in 2001 and by 2012, 22 states had engineering requirements for students in grades K-5 (Carr et al. 2012). Since the late 1990s, millions of students have had some form of engineering experience, but those experiences and state standards have had considerable variation (Carr et al. 2012; National Research Council 2009). In an effort to formalize and mainstream engineering as a part of science education, a committee of state representatives and education experts came together to create the Next Generation Science Standards (NGSS) using the National Research Council (NRC) publication, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NGSS Lead States 2013). As part of this framework, students will be expected to understand the role of science and engineering in solving societal problems (National Research Council 2012). Engineering in the NGSS is presented as design and compared to scientific practices. Students will learn about engineering in their science classes and will be expected to know that engineers define problems and design solutions, as compared to scientists who ask questions and construct explanations of natural phenomena (NGSS Lead States 2013). To develop deeper levels of understanding, students living in states that have adopted the NGSS will be assessed based on their abilities to use the practices of science and engineering in addition to their knowledge of basic science concepts. In 2014, the National Assessment of Educational Progress (NAEP) added another standardized test to its repertoire: The Technology and Engineering Literacy (TEL) assessment (National Assessment Governing Board 2013). This national assessment will compare students from all states, not just those that have adopted NGSS. Together, NGSS and TEL have created urgency for engineering and technology to be integrated formally into K-12 education in the United States. For most teachers, however, this is a new content area, creating a pressing need for professional learning and development specific to engineering and technology.

Similar to other science reform efforts, professional development has emerged as the vehicle to bring engineering into elementary classrooms. Although engineering in elementary schools is still in its infancy, many different professional development programs focusing on engineering have been suggested, designed, and implemented (e.g., Brophy et al. 2008; Cunningham 2009; Hailey et al. 2005; Yoon et al. 2013; Zarske et al. 2004). While there is some consensus in what constitutes high quality professional development (Supovitz and Turner 2000), similar programs can produce different results due to varying teacher background and classroom implementation contexts (Guskey 2003). Even in cases of high quality professional development where there is ongoing teacher support, teachers take the curriculum and implement (or in some cases, do not fully implement) it within their unique classroom, school, district, and community cultures. Teachers who attended the same professional development opportunities may have varying degrees of implementation fidelity due to these specific contextual factors. These differing circumstances play an important but often under-studied role in the long-term implementation or discontinuation of curricular reform. Therefore, there is a need for more in-depth examinations of the contextual elements that hinder or support professional development efforts for long-term implementation (Banilower et al. 2007).

With the wider adoption of engineering in the U.S., there is much to learn about how professional development can serve to initiate engineering in elementary classes and also lay a foundation for engineering to become a permanent fixture in K-12 education. Although there is great urgency to prepare teachers to integrate engineering, true teacher learning and long-term change require more than just the actual venue where teachers are to learn (e.g., workshops and online courses). Teachers will implement engineering in the context of their classrooms within the larger context of the schools themselves which exist within school districts and the local community. Some of these contexts will be more supportive of long-term curricular change and some will perhaps hinder reform. Research that closely examines the cases where engineering has and has not become sustaining can serve to enrich the engineering education community's depth of knowledge on how professional development for engineering can purposefully seek to address these contextual factors.

Teacher professional development for engineering

Sustained curricular reform requires enhancing the knowledge and practices of in-service teachers primarily through ongoing teacher professional development (TPD) (Darling-Hammond and Richardson 2009). With the adoption of the NGSS, engineering will formally enter many science classrooms around the U.S. (NGSS Lead States 2013), but this does not guarantee long lasting adoption of engineering curricula. To achieve successful reform, many in-service teachers will need to learn content, skills, and pedagogical practices that pertain to engineering (Brophy et al. 2008). Current elementary teachers have not had formal training in engineering education previously available to them and therefore, TPD must play a large role in preparing teachers to teach engineering in a sustainable manner.

For TPD to be successful in preparing teachers for this curricular transition, lessons learned from the program in all areas, not just content, must be considered. Characteristics of successful high-quality professional development have been reported in various studies (e.g., Banilower et al. 2007; Custer and Daugherty 2009; Darling-Hammond and Richardson 2009; Guskey and Yoon 2009) and share many similarities. The National Comprehensive Center for Teacher Quality (Archibald et al. 2011) reports on these similarities and states that TPD should have:

1. Alignment among school goals, state and district standards and assessments (including formative teacher evaluation), and professional learning activities
2. Focus on core content and modeling of teaching strategies for the content
3. Inclusion of opportunities for active learning of new teaching strategies
4. Provision of opportunities for collaboration among teachers
5. Inclusion of embedded follow-up and continuous feedback

These criteria for high quality TPD speak to conceptual change and understanding of the content and methods of instruction, which are essential for sustained reform stemming from professional development.

In addition to the quality of the TPD, the individual school contexts largely determine how successful a curriculum reform effort is (Guskey 2003). For example, individual schools have varying student needs. Schools with a high percentage of students from low socio-economic families will have different challenges than schools situated in affluent neighborhoods. Students in more affluent areas may have higher levels of exposure to engineering through family or friends, whereas some students in economically challenged environments may not have had any previous exposure to engineering. Student needs will likely influence the priorities of the school administration (Supovitz and Turner 2000). Yet, how engineers fits in with these contextualized student needs may not be clear to administrators. Districts and administrators may have varying views on issues such as the importance of engineering in their school and the level of training teachers need to teach effectively.

Individual teachers can also directly and indirectly influence whether the curriculum changes are long-lasting. For example, some reform efforts have not been successful due to the neglect of teachers' existing attitudes, beliefs, and knowledge (Van Driel et al. 2001). Teacher implementation can influence student outcomes and lead to minimal or superficial changes in teaching practice (Archibald et al. 2011; Durlak and DuPre 2008). This is particularly concerning considering that one study of K-12 teachers found their level of familiarity with design, engineering, and technology as well as their confidence in their ability to teach engineering to be quite low (Yasar et al. 2006). Teachers' attitudes about the importance of teaching engineering to their students could influence the effort that they exert in learning for themselves, as well as how they instruct their students.

Another important contextual factor is the level of peer support that teachers have. A supportive network of peer collaborators and administrators can promote sustained reform; at the same time, the lack of a supportive network can hinder the long-lasting impact of professional development (Roehrig et al. 2007; Villegas-Reimers 2003). Teachers can provide feedback to each other regarding implementation issues as they arise. If the school culture is such that teachers rarely collaborate, someone with no prior experience in hands-on teaching methods may become quite frustrated with the challenges such instruction presents.

Without sustained change in teaching practice, knowledge gains from professional development are inconsequential (Archibald et al. 2011). For long-lasting reform, there must be buy-in from the entire scholastic community and an understanding of how the context affects sustainability. While some literature in TPD speaks to the importance of contextualizing professional development for sustainability (Guskey 2003; Supovitz and Turner 2000), questions regarding the impact different contexts have on sustained reform and what is meant by contextualizing professional development activities on the whole remain unanswered. Additional studies must be undertaken to better understand how TPD can address contextual issues and support long-lasting reform (Banilower et al. 2007; Guskey and Yoon 2009).

Purpose of research and research questions

The purpose of this research is to explore what contextual factors were associated with one elementary school's long-term adoption of an engineering curriculum and another school's discontinuation of that curriculum. Through the case study method, we studied two elementary schools within the same school district that received the same professional development opportunities with engineering, yet had different outcomes in sustaining the engineering curriculum. We examined teacher experiences with implementing engineering lessons and the resulting student outcomes. According to Yin (2009), the case study research method is particularly advantageous when "how" or "why" questions are being asked about a contemporary set of events, in which the researcher has no or little control. One elementary school, Fairview (pseudonym) chose to further expand their implementation of engineering to include more teachers in the building, whereas another elementary school, Eastwood (pseudonym) chose to discontinue after the initial commitment period of two years. The following research questions were asked: (a) How did teachers report implementation of engineering in their classrooms? (b) What were teachers' perceptions about their level of in-school support? (c) What were teachers' perceptions about the value of teaching engineering to elementary students? (d) What were the changes in students' science, technology, and engineering knowledge? and (e) What were changes in students' engineering identity development?

Project background

As part of a National Science Foundation (NSF) grant, our team partnered with a large school district in south central United States to provide teacher professional development in engineering to elementary teachers in grades two, three, and four. Teams of teachers from 15 schools over the course of the program voluntarily applied and committed to participate for two years of ongoing TPD, which is henceforth referred to as this project. No prior science, technology, engineering, or mathematics (STEM) certification or experience was required for participation. Teachers initially attended a week-long summer academy on content and pedagogy designed for them to: (1) understand and communicate a broad perspective of engineering in nature and practice; (2) differentiate and find similarity between engineering and science thinking; (3) lead classroom discussions on what engineers do and how engineers solve problems; and (4) use problem-solving processes, such as science inquiry, model development, and design processes in their classroom instruction. During the school year, an on-site teacher liaison (a former elementary science education specialist for the district) supported teachers and provided additional after-school workshops. After the school year, teachers attended a three-day follow-up summer academy.

By participating in the project, teachers committed to teaching the following lessons: (1) introductory definitions of engineering and technology, (2) introductory engineering design process, followed by (3) an Engineering is Elementary (EiE) unit (Cunningham 2009). The district administration helped decide which unit would be adopted by each grade according to alignment with district science curriculum standards. The second grade teachers implemented *A Work in Process: Designing a Play Dough Process*, focusing on the scientific principles of solids and liquids while incorporating chemical engineering through a capstone design project where students alter ingredient quantities to create dough to play with (Cunningham et al. 2006). Third grade teachers implemented *Marvelous Machines:*

Making Work Easier, focusing on the scientific principles of simple machines while incorporating industrial engineering through a capstone design project where students create an industrial process to move objects from one point to another (Cunningham et al. 2005). Fourth grade teachers implemented *Thinking Inside the Box: Designing a Plant Package*, focusing on the scientific principles of what plants need to stay alive while incorporating packaging engineering through a capstone project where students create a box to ship a plant in that will keep the plant alive for a few days (Cunningham et al. 2006). Each EiE unit begins with a preparatory lesson to prompt students to think about technology and engineering followed by four unit-specific lessons (Cunningham 2009). The first lesson presents a storybook to set the context, formulate a problem, and integrate literacy. The second lesson is an introduction to the field of engineering that would solve the given problem. The third lesson focuses on the scientific principles needed to solve the engineering problem. The fourth and final lesson is an engineering design capstone project that solves the problem given in lesson 1 using the engineering and science principles presented in lessons 2 and 3.

Over the five-year course of the project, schools expanded and contracted the number of teachers who taught engineering. By the end of the five years, 11 schools had discontinued after the initial two-year commitment; five sustained beyond the commitment. We chose to examine one school that sustained the integration of engineering lessons and one that discontinued.

Schools and students

Fairview Elementary School, which chose to continue integration of engineering lessons, is located in a large suburban area. In the first year, Fairview Elementary School was not designated a Title I school, but in the following year, it became Title I eligible due to a slight increase in the percentage of students qualifying for free or reduced lunch. The student to teacher ratio in this school was 18:1. Eastwood Elementary School, which chose to discontinue integrating engineering after two years, is located in a large city. In both the first and second school years, it was a Title 1 school with a high percentage of students qualifying for free or reduced lunch. School size was smaller than Fairview with a higher percentage of Hispanic students. Student to teacher ratio in Eastwood was 15:6 in 2008–2009 and 16:3 in 2009–2010. Table 1 shows detailed demographic information about each school and its students.

Teachers and their classes

The demographic information for all teacher participants of this study is shown in Tables 2 and 3. In the first year, four Cohort 1 teachers (Camille, Joe, Brandy, and Heather) at Fairview Elementary School attended the summer academy, implemented engineering lessons, and were interviewed at the end of the school year. In the second year, three Cohort 2 teachers (Pat, Michelle, and Quin) attended the summer academy, but interviews were only possible with two Cohort 2 teachers (Pat and Michelle) and three Cohort 1 teachers (Camille, Joe, and Heather). Joe was the only teacher from Fairview that had previously worked in a STEM field; he had been a production manager prior to teaching. All seven teachers taught in self-contained classrooms, meaning they each taught all subjects to the same group of students throughout the day.

While five Cohort 1 teachers at Eastwood Elementary School attended the first year Summer Academy, only three taught engineering in the following academic year (Matt, Bailey, and Haley). All three were interviewed at the end of both school years. In the

Table 1 School and student characteristics in academic years 2008–2009 and 2009–2010

Characteristics	Fairview		Eastwood	
	2008	2009	2008	2009
School size	932	950	598	594
Title I status	No	Eligible	Yes	Yes
Free/reduced lunch status (%)	40.0	43.0	84.6	88.6
Students' gender				
Boy (%)	51.2	50.8	53.0	51.0
Girl (%)	48.8	49.2	47.0	49.0
Students' ethnicity				
American Indian/Alaska Native (%)	0.2	0.5	0.8	0.3
Asian and Pacific Islander (%)	21.9	22.3	1.0	0.0
Hispanic (%)	20.4	20.7	74.1	76.2
African American (%)	38.8	38.7	12.8	16.5
White (%)	18.7	17.7	11.2	6.9

Source National Center for Educational Statistics (n.d.)

Table 2 Demographic Information of the participating teachers in Fairview Elementary School

Name[a]	Camille	Joe	Brandy	Heather	Pat	Michelle	Quin
Cohort	1	1	1	1	2	2	2
Interviewed year	2009, 2010	2009, 2010	2009	2009, 2010	2010	2010	None
Gender	Female	Male	Female	Female	Female	Female	Female
Race	White	White	White	White	White	White	White
Grade level	2	2	3	4	2	3	3
Highest education	BA (Sociology)	M.Ed.	BA	BA (Political Science)	BA	MA	BA
Certificate	ESL	–	–	ESL	ESL	GT	–
Years as a full-time teacher at their start in project	7	7	4	7	14	31	3

BA = Bachelor of Arts; M.Ed. = Master of Education; ESL = English as Second Language teacher certificate; GT = Gifted and Talented teacher certificate

[a] All names are pseudonyms. Unless otherwise noted, degree area is elementary education

second year, no new teachers joined the project, though the three Cohort 1 teachers continued to implement engineering lessons. One teacher, Matt, had a Bachelor's degree in Mathematics and also obtained a Mathematics certification prior to joining the project. Eastwood's school structure was such that teachers were specialized in one subject. They did not teach the same students all day, but rather, taught the same subject all day.

Methods

This study spans the two year commitment the schools gave to participating in the project, from 2008 to 2010. Both qualitative and quantitative methods were used to address the research questions. The procedures used are discussed below. Table 4 lists each research

Table 3 Demographic information of the participating teachers in Eastwood Elementary School

Name[a]	Matt	Bailey	Haley
Cohort	1	1	1
Interviewed year	2009, 2010	2009, 2010	2009, 2010
Gender	Male	Female	Female
Race	Hispanic	White	White
Grade level	2	3	4
Highest education	BA (Mathematics)	BA (Psychology)	BA, MA (Business Administration)
Certificate	Math EC-4	–	Language Arts for grades 1–8
Years as a full-time teacher at their start in project	4	1	15

[a] All names are pseudonyms

Table 4 Research questions and data sources

Research question	Data source(s)
How did teachers report implementation engineering in their classrooms?	Debriefs Interviews
What were teachers' perceptions about their level of in-school support?	Interviews Focus Groups
What were teachers' perceptions about the value of teaching engineering to elementary students?	Interviews
What were the changes in students' science, technology, and engineering knowledge?	Student Knowledge Tests (SKTs) (Dyehouse et al. 2011; Yoon et al. 2014)
What were changes in students' engineering identity development?	Engineering Identity Development Scale [EIDS] (Capobianco et al. 2012)

question mapped to the corresponding data source. We obtained Institutional Review Board approval, and prior to beginning the teacher professional development, teachers gave their informed consent. In addition, only data from students who signed and returned the student assent and parental consent were used in this study. Only members of our research team who were not part of the teacher professional development took part in analyzing data.

Qualitative methods

Our qualitative methods were informed by a phenomenological perspective, to understand more about teachers' perceptions and experiences with engineering lessons. Phenomenology is a tradition in qualitative research that seeks to understand the lived experience of the phenomenon (e.g., integrating engineering into elementary lessons) by the group of people (Patton 2002). At the end of each school year, the team of researchers and assistants conducted 30–50 min semi-structured interviews. In the first year, the interview protocol focused on the exploration of teachers' perspectives and experiences with implementing engineering in their classrooms as well as questions related to their professional development needs. A revised protocol was used in the second year to understand more about classroom practices and engineering implementation methods.

Focus groups were performed in the winter of the second year of the project to elicit teacher feedback on the barriers and supports to integrating engineering in their schools. At Eastwood, only two of the teachers, Haley and Bailey, participated in the focus group. All seven teachers from Fairview attended the focus group session.

The 2 years of interviews and the focus groups were treated as three sources of data. Interviews and focus groups were transcribed verbatim and then approached through inductive and deductive methods, based on guidelines set out by Patton (2002). Phenomenological analysis, "seeks to grasp and elucidate the meaning, structure, and essence of the lived experience of a phenomenon for a person or group of people", (Patton 2002, p. 482). Inductive and deductive approaches to qualitative analysis were used in a complementary manner. Based on the literature review and building our previous research, (Yoon et al. 2013) we identified initial areas for our coding scheme. Next, we read through transcripts using the inductive technique of open-coding and possible new categories were allowed to emerge. This allowed for findings to emerge from the data, as well as a check for cohesion with the literature on successful TPD and our previous research. To ensure reliability and validity of our qualitative findings, two of the authors worked together in a collaborative and participatory process in each stage of analysis and achieved consensus. Differing opinions regarding potential codes and broader themes were openly discussed until mutual agreement was found, based on definitions given to the categories. A matrix was used to log the frequency of the codes occurring. Broader themes were found by combining individual codes. The themes found in the interviews and focus groups were corroborated and the data was searched for contradictory examples of the theme. Assertions were then developed to help aid in the interpretation of the findings.

Quantitative methods

The student outcomes experienced through the integration of engineering lessons into classrooms was examined through quantitative methods using two assessments. The Student Knowledge Test (SKTs) (Dyehouse et al. 2011; Yoon et al. 2014) was used to assess student knowledge change in science, technology, and engineering. SKT is a multiple-choice test which consists of items mapped to the learning objectives of the lessons, for a total score between 0 and 15. The items were developed by a diverse group of STEM education faculty, researchers, and elementary educators (Yoon et al. 2014). There are two subcomponents of the SKT: engineering and science. The engineering questions were mapped to learning objectives centered on a basic understanding of engineering design, technology, and the work of engineer concepts. These engineering and technology related learning objectives were part of the supplemental lessons taught. The science questions were developed based on the learning objectives associated with each EiE unit. Authors reported a range for item difficulty from 0.20 to 0.81 when used as pre-test and from 0.30 to 0.90 when used as post-test. Similarly, the instrument presented a discrimination coefficient between 0.11 and 0.43 for the pre-test and between 0.25 and 0.52 for the post-test (Yoon et al. 2014). In addition, a confirmatory factor analysis performed by the authors showed that all items loads were significant for measuring the same construct. Cronbach's α values were reported as 0.67 for the pre- and 0.79 for the post-test.

The Engineering Identity Development Scale (EIDS) (Capobianco et al. 2012) was used to assess students' development in their understanding of the work of engineers and their aspirations towards engineering. There are two factors on the EIDS: *Academic Identity* and

Table 5 Description of assessment instruments used in study

Instrument	Construct/topic	# of items	Scale	Total score	Reliability
SKTs (Dyehouse et al. 2011; Yoon et al. 2014)	Science, Engineering & Design Knowledge at each grade level		Multiple choice		
First year versions					
2nd grade		12		16	$r_\alpha = 0.87$
3rd grade		10		10	$r_\alpha = 0.69$
4th grade		14		13	$r_\alpha = 0.69$
Second year versions					
2nd grade		10		15	$r_\alpha = 0.84$
3rd grade		10		15	$r_\alpha = 0.80$
4th grade		10		15	$r_\alpha = 0.79$
EIDS (Capobianco et al. 2012)	Academic identity	5	3-point Likert	15	$r_\alpha = 0.58$
	Engineering career/aspiration	11		33	$r_\alpha = 0.76$

r_α indicates Cronbach's alpha reliability coefficient

Engineering Career/Aspirations. *Academic Identity* refers to how well students identify within their school and feel about their academic abilities. *Engineering Career/Aspirations* refers to students' understanding about the work of engineers and their aspirations to working in engineering-like environments. Table 5 summarizes the characteristics of each assessment instrument and lists references that contain information about the psychometric properties of each instrument. The instruments were administered to students at the beginning and end of each school year. Only students that took both the pre-test and post-test are included in the data analyses. The number of students that turned in parental consent and student assent in each classroom is considerably small. This was particularly true at Eastwood, where only three second graders turned in the consent and assent forms and took the pre-/post-test in 2008 and only four fourth graders in 2009.

Analysis

Due to small sample sizes, the SKT scores in each classroom were analyzed through descriptive statistics. Because students in the three grade levels (2, 3, and 4) were all given the EIDS, data were combined to test for significant changes in pre- and post-scores on the engineering factor for each year at both schools in a paired sample t test. Although the post-test of the EIDS did not fit into acceptable normality range, the distribution of the gains in scores was evenly distributed. Therefore, nonparametric alternatives were not estimated. To determine whether or not the mean changes in students' attitudes toward engineering were different between schools, the Conover and Iman (CI) (1982) method of rank transformation was used prior to an Analysis of Covariance (ANCOVA) due the small sample sizes, the unequal group sizes, and nonnormality of the dependent variable. Rheinheimer and Penfield (2001) suggested that this nonparametric method of ANCOVA has considerably more power than the F-test.

Results

Results are presented in order of research question, followed by a discussion of emergent findings from interviews and focus group data. Quotes are presented with the pseudonym and where the quote came from (i.e., year one, year two of interviews or focus group).

How did teachers report their implementation of engineering in their classrooms?

Preparation and completion of lessons

During the interviews, teachers were asked how they prepared students for the engineering lessons, whether they had implemented all of the engineering lessons associated with the Academy, and what type, if any, modifications to the lessons were made. This data was also solicited through lesson debriefs. Teachers at both schools reported similar ways of preparing their students for the EiE lessons, based on the training they received. Teachers started with activities to define engineering and technology and then did an introductory engineering design process activity. In addition, teachers at Fairview brought in engineers to speak with their classes and adopted additional engineering design activities during the school year. Teachers within both schools varied in the number of lessons associated with the project they actually taught. For example, in 2008–2009, each school had one teacher that did not complete all four lessons that comprise an EiE unit. In 2009–2010, two teachers at Fairview and one teacher at Eastwood completed only three of the lessons. All other teachers at both schools reported completing the full unit of four lessons. Table 6 lists student results with the number of lessons implemented in each classroom, based on the teacher debriefs. Teachers at both schools reported implementing the lessons closely to how they are described in the EiE teacher implementation guide, making small adjustments based on their students' needs.

Fairview

Teachers report they made few modifications to the lessons. Nearly all of the teachers added engineering design activities and used a school-wide tool, circle maps, to help students understand engineering concepts and enrich their engineering lessons. Some had engineers visit their classrooms. For example, Joe discussed having a local engineer come and present projects he works on.

> Joe, year one: *We were very fortunate that we had an engineer come from, I think it was Lockheed Martin. He came out to talk to the kids and actually showed em a couple of films of projects that he was working on. So they got to physically meet one.*

Teachers found ways to incorporate the engineering design process in ways beyond what was presented at the summer academy. Engineering themes were brought into math, language arts, and social studies, as well as school-wide activities. For example, Camille discussed finding an engineering design activity to be used in support of language arts.

> Camille, year two: *Well, I think we're going to tie it in with A Chair for My Mother. Because I found one online where you have to build a person out of gumdrops and toothpicks, and they have to be sit on the edge of your desk; and then the next step is the kids have to build some kind of chair for the person to sit on because—I mean,*

Table 6 Descriptive statistics for students knowledge test (SKT) scores by classroom

School/grade	2008								2009							
	# of EiE lessons	*N*	M_{pre}	SD_{pre}	M_{post}	Ave. % Correct	SD_{post}	Δ	# of EiE lessons	*N*	M_{pre}	SD_{pre}	M_{post}	Ave. % Correct	SD_{post}	Δ
Fairview																
2	4	8	13.38	1.85	15.38	96.13	0.92	2.00	3	11	5.27	1.79	11.00	73.33	3.13	5.73
2	4	6	14.17	0.98	14.83	92.69	0.41	0.66	3	13	6.08	2.46	10.08	67.20	2.78	4.00
3	3	14	3.65	1.78	7.57	75.70	2.38	3.92	4	13	4.85	2.12	12.00	80.00	1.73	7.15
4	4	16	7.75	2.87	10.06	77.34	2.74	2.31	3	18	8.67	3.14	11.28	75.20	1.87	2.61
2[a]									3	15	5.27	1.53	10.47	69.80	2.8	5.20
3[a]									4	11	4.27	1.74	10.73	71.53	1.68	6.46
3[a]									4	15	6.27	2.02	9.47	56.47	2.67	3.20
Eastwood																
2	4	3	10.33	2.89	13.67	85.44	0.56	3.34	4	7	5.29	0.76	9.00	60.00	3.69	3.71
3	2	13	4.08	1.61	5.23	52.30	1.54	1.15	3	5	3.60	1.34	8.60	57.33	1.34	5.00
4	4	8	5.25	1.49	5.63	43.31	1.60	0.38	4	4	8.5	2.65	12.00	80.00	2.65	3.50

[a] Teachers began in second year of project. In 2009, the 2nd and 4th grade versions of SKT decreased number of items

it's a story about a house that burns down and then the mom wants a new chair. So we're going to do that. We can tie it through math, language arts, maybe even social studies because they have a different cultural background. And then I've also pulled something for the three pigs, having them work on the third house like there are no bricks; they have to come up with something else, whether it's marshmallows or craft sticks, paper clips, that kinda thing. We're going to get 'em to build it, and then we're going to test it with a hair dryer or a fan or something.

Eastwood

Teachers reported they presented engineering activities shown during the summer academy, with modifications in the first year due to time constraints or students' language barriers. For example, Heather discussed shortening the lessons to make time to implement them.

> Heather, year one: *[S]ometimes I shortened stuff like when we read through the book, I didn't read the whole book. I just hit on certain parts of the book.*

Most teachers worked to relate the engineering ideas to their students' experiences and language abilities. For example, Bailey discussed thinking ahead of implementation about how to relate the engineering concepts to her English language learners.

> Bailey, year two: *Well, I guess just that: I had to think about, what have they seen? What have they experienced? What do they know? And then try to bring that in first. Before kinda giving 'em everything out of here or something out of the lesson, try to get it in their world.*

Subject integration

Teachers at both schools were asked about the integration of engineering with their other subject matter. Integration is considered any activity that reinforces or connects with another subject that is not engineering, such as science, mathematics, language arts, or social studies.

Fairview

At Fairview, teachers found ways to integrate engineering with many other subjects by reading engineering related books as part of their reading lessons, using the engineering design process as a proxy for the writing process, and discussing technology and problem solving in social studies. They also incorporated additional engineering design projects that worked with other subjects. Many felt that it was essential to integrate engineering into other subjects in order to teach all required subjects and engineering. Brandy discussed being able to make connections between the engineering lessons and curriculum standards in math and social studies.

> Brandy, year one: *[E]ven with technology, it's a social studies [standardized test skill]and so I counted that as my social studies for the day, so, I was able, being a self-contained teacher it makes it a lot easier to incorporate these activities in what I already know from our curriculum.*

Camille discussed creatively that finding was to integrate the curriculum and emphasize the importance of integration.

Camille, year two: *Well, we used a lot of literature to tie in. …We've pulled in science, social studies, math, and language arts. I'll be interested to see if we can—I guess we did kinda pull in some artwork when we did our bat puzzles, too. So, if we can't integrate it, we can't do it.*

Heather discussed extemporaneously applying engineering design to a classroom problem.

Heather, focus group: *We had a math assignment and it involved either me doing a lot of cutting or the students doing a lot of cutting so we designed an assembly line process.*

Eastwood

Teachers found that engineering mainly integrated with science and math. Some saw additional integration opportunities but found it difficult as they mainly taught only science. Haley, the science specialist, chose to work with a math teacher who had not attended the professional development, specifically because she believed that teacher would reinforce engineering during mathematics.

Haley, focus group: *And I picked a teacher that I knew, she's the math teacher, for all the classes, and I picked her because I knew she would tie it back to math, and the kids have told me, "oh, last week, Mrs. So-and-so, she was talking about how engineering is in math too, and how this is like engineering" so I chose her for that reason, because I knew she would help the kids make connections.*

Bailey discussed that in her second year of teaching engineering, she was more able to make connections between engineering and other subjects.

Bailey, year two: *Yeah. This year everything has kind of come together a little bit more. Like I'm seeing, you know, more of this discipline in this discipline, and I'm seeing more, you know, I'm kinda like, "Do you remember when we did this in this class?" you know, because I do teach math and science and social studies and everything.*

Time constraints

Teachers from both schools described time as a limiting factor for engineering lesson planning and implementation, often discussing the conflict between required activities and assessments and engineering lessons.

Fairview

Time was mentioned as a constraint by some teachers, though all teachers incorporated engineering activities above and beyond those expected. Joe discussed the time constraints as not due to the added engineering lessons, but rather the added lessons were just one aspect of many expectations placed on him.

Joe, year two: *Time management has become a big issue, not just because of this but because of everything else they're having us to do.*

Heather discussed a desire to incorporate the lessons further, but that with the adoption of new district curriculum, she did not have the time to expand engineering in her classroom, as she would have liked.

> Heather, focus group: *I really wanted to start this year designing new activities incorporating stuff and I have more ideas right now, it's just the time thing right now. I'm at school every night until after six and that's just taking care of all of the new curriculum we have right now, all the new documentation they want.*

Eastwood

Time was often mentioned as a constraint and the reason for not completing as many engineering activities as desired. Haley discussed giving students the supplemental worksheets to the activities because of time constraints.

> Haley, year one: *We didn't do, like, any of those worksheets that went with that book just 'cause there was– there wasn't time.*

Matt discussed the district-level expectations as being too high.

> Matt, year two: *Um, the same things that happened this year were the same things that happened last year: They have us doing too many things.*

Bailey discussed not having as much classroom time for lessons as she thought was needed, due to the need to prepare students for standardized testing.

> Bailey, year two: *Time needed for preparation – pretty well. Time needed for implementation – I'm going to say barely adequate on that one. Because—well, the way I'm reading this—time needed for implementation—just… not having enough time to put engineering in the lesson plans. You know, with testing and every… You know, I've got an end-of-the-year science test this Friday, and I've got to get through everything to get to that test. First half of the year, I've got a mini-test in December. I've got to get through everything to get to that mini-test.*

What were teachers' perceptions about their level of in-school support?

Administrative support

During the interviews, teachers were asked whether they felt their administration was supportive. All teachers at both schools answered the question with "yes". However, what they said after their initial response varied in the level of support that they described and the examples provided. Teachers also discussed their principal during the course of the interviews and focus groups at times when the interviewer did not specifically bring up administration. In addition, in the second year of the project, the district implemented new curriculum standards, based on a state-wide testing initiative. Teachers at both schools described the stress and pressure felt from the new curriculum standards.

Fairview

Teachers described their principal as flexible, not overbearing, and excited about engineering. The teachers described the principal as extremely supportive of engineering and of activities to promote engineering in the whole school. They also discussed district level administrative support as a necessary component of increased engineering integration. For example, Heather discussed the principal announcing over the school intercom what was going to be happening in engineering classrooms.

Heather, year one: *She announced over the announcements when the kids were doing special, you know, something with the engineering project and I thought that was neat.*

Michelle discussed how the principal helped make connections with local engineers to come into classrooms, and Heather was assisted by the principal in writing a grant to pay for additional engineering materials.

Michelle, focus group: *I know that our administrator is excited about bringing engineers into the school so she welcomes new ideas and working with the community so that helps us too.*

Heather, focus group: *One thing too, and I've spoken to our principal is writing some grants for the Spring to get all the books from the science museum in Boston of the ones we don't have per grade level to get sets for the library so we can all use those. She's going to help me write a grant to get the extra thousand dollars to get those sets of books into have some other kinds of activities to do.*

Eastwood

In the first year, teachers described the principal as being open to engineering lessons, but also discussed a desire to demonstrate the value of engineering in the classroom. Although the principal had allowed five teachers to attend the Academy in the first summer, before the start of the school year, she decided only three would be allowed to implement engineering lessons. They spoke about the principal as very focused on student achievement on the state standardized tests. They discussed wanting to show that the engineering lessons provided positive student experiences and increased learning in order to gain more principal support for engineering integration. For example, Bailey and Haley discussed a desire to prove that the engineering lessons are supportive of the standardized tests.

Bailey, year one: *Math and reading and [state standardized] tests are very important to her. Being an exemplary school is very important to her. And I think that you know, it is my belief that this can become exemplary, you know, doing these things, but I…but I've got to prove it to her. You know…I've got to be able to prove that – going away from our objective list or our curriculum guide…we can still get the kids where they need to be.*

Haley, focus group: *If we could know how to tie it in, and show her that it's working on the core subjects, give her concrete evidence that it's working in the core subjects, I think.*

Matt mentioned the principal's decision to not allow as many teachers to implement engineering as had attended the academy.

Matt, year one: *I mean, even though she didn't let Jen and them, she let me do it and it was hard, you know, 'cause I have to put it in Spanish still in this classroom.*

Curriculum constraints

For this school district, engineering lessons were above and beyond the typical curriculum and were at times considered to conflict with requirements, such as the proscribed curriculum or standardized test. Discussions of how the engineering lessons helped or hindered the curriculum or standardized testing were coded.

Fairview

Teachers overall did not feel that the curriculum or standardized tests constrained them while teaching engineering. Camille mentioned a curricular conflict based on timing the first year while Heather discussed improved curriculum integration based on curricular changes in the second year.

> Camille, year one: *Well, the play dough unit was, you know, great, but our curriculum has us teaching solids, liquids, gases almost at the beginning of the year and play dough was way too much for them at that point.*

> Heather, focus group: *We're actually doing a lot more; it's aligned with the way the district has changed the curriculum to fit into our geometric measure and our geometric shapes, our 3D rectangular prism, cubes, that kind of stuff. That's part of what I've written into the lesson plan for Thursday. It's identifying to the kids what shapes I want to be able to see when they're making the pop up cards so this will be a really good time for that. Also the measurement of the perimeter of the items so I'm tying all of these in because perimeter and area is what we're actually focusing on right now along with the 3D shapes and the geometric angles, parallel lines.*

Eastwood

Teachers at Eastwood were unsure how to integrate engineering into their proscribed curriculum. Teachers perceived that the principal placed a very high value on the state standardized test preparation, adding additional pressure to focus mainly on subjects found on the exam. Bailey discussed changing her plan of when to implement engineering based on the standardized test priority.

> Bailey, year one: *Our principal, you know…specifically asked me to teach math…to get our kids ready for the [standardized] test. So I…had to kinda put engineering on the back seat for a little bit.*

Haley discussed the pressure teachers feel to have students that perform well on the test.

> Haley, year two: *So the pressure with the test is just huge, the state testing, and I don't see that changing ever, so we just have to find a way to work around it, you know?*

Teacher community

Teacher community is here defined as communication and collaboration between teachers within the school. Informal communication and formal collaboration (co-teaching and lesson planning) were examples of cooperation and community. Teachers at both schools discussed communication with other teachers as desirable in learning to implement the engineering lessons. However, teachers at Eastwood were not as connected to each other as the teachers at Fairview.

Fairview

Teachers described multiple methods for collaboration throughout the program, from planning lessons in teams to combining classes and co-teaching. This collaboration extended beyond grade levels; teachers of different grades also collaborated and pulled classes together for the lessons. By the second year, fewer teachers co-taught but still discussed the engineering lessons in teams. The new cohort of teachers, Michelle, Pat, and Quin, spoke of observing and collaborating with more experienced teachers. They expressed this helped them to feel more comfortable teaching engineering for the first time.

> Camille, year one: *And, even though we had used them before, we always combine our classes on these kinda things. Two adults is better than one.*

> Michelle, year two: *We had three people. When we were able to get together and meet and work something out, it went more smoothly, we were more time-efficient.*

> Heather, year two: *We've talked about that in our group because we do a lot of that, you know, "Well, what are you doing?" (laugh) you know?*

> Camille, focus group: *We had some kindergarteners come down. They [her second grade students] made their design and they [kindergarteners] were our consumer group.*

Eastwood

Teachers described a desire for collaboration and discussed a lack of collaboration in planning lessons in the first year of interviews. They described preparing for the lessons using the manual provided at the summer academy and the notes they had taken. Haley discussed the challenge of teaching only science rather than being a self-contained classroom with the same set of kids all day. She found it difficult to integrate engineering with other subjects.

> Haley, year one: *–[B]ecause we're departmentalized our teachers can't make those connections.*

In the second year, only one teacher, Bailey, discussed collaboration. One teacher per grade (2nd, 3rd, and 4th) taught engineering. Because there were only three teachers, each implementing a different engineering unit, there were no other teachers in the building to co-plan or discuss specific lessons with. Bailey discussed a desire to learn from other teachers and collaborate, but she was the only science teacher for the third grade.

> Bailey, year one: *I'd like to talk to some people, other schools and just see, well, where did you put it did you just add it?*

> *I would have to call [name of the liaison] or somebody and say, what is it that I need to do?*

> Bailey, focus group: *Because I am the science person, I do it as a class, I mean, each class that comes to me, we do the engineering.*

What were teachers' perceptions about the value of teaching engineering to elementary students?

Teacher attitudes regarding engineering were characterized by statements about their personal feelings, such as "I enjoyed" or "my favorite". No instance of negative attitudes towards the engineering curricula was found in any interview, although teachers were honest about challenges they faced in the implementation of lessons. They discussed ways of further improving how they implemented the engineering lessons and small changes that would contribute to successful lessons.

Fairview

The teachers described a desire to teach engineering.

> Brandy, year one: *I'll do it even if you don't come back next year.*
> Joe, year one: *I've really enjoyed it. It's been a fun year for me.*

Heather described not being a math or science "person", but that she genuinely enjoyed teaching engineering.

> Heather, year two: *And two years ago, when I was approached and asked "Do I want to do this?" that was my biggest motivation, because I am not a science person, I am not a math person, but I love the idea of creating problem-solvers and true, real-life thinkers.*

Eastwood

In the first year, teachers found some frustrations and setbacks during the engineering lessons but discussed engineering and their students' responses to engineering in a positive way. For example, Bailey discussed uncertainty about how the engineering lessons specifically supported their curriculum standards.

> Bailey, year one: *Well…I think I wasn't real sure where to put 'em. I wasn't really sure…I mean I know they're math, and I know they're science. I know…that they're all involved, but I just – I didn't know where…and what I was doing in my curriculum that I go by…I wasn't sure where to put it.*

Despite the implementation frustrations, Bailey discussed being surprised by students' ability to design that influenced her to raise her expectations of them. A year later, she discussed again her own learning as a result of implementing the lessons.

> Bailey, year one: *You know, this, I mean, they're third grade. They're eight-nine years old but…they impressed me. They really did. And I expected more from them, because of, partly because of their excitement for it.*

> Bailey, year two: *Well, I will say that I have really enjoyed these past two years… working with this, learning so much. I want to continue learning.*

Teacher perceptions of student enthusiasm and learning

Teachers at both schools perceived high levels of student enthusiasm due to the engineering lessons. They also perceived gains in understanding engineering, technology, science, mathematics, and improvement in interpersonal skills like teamwork. Teachers reported that the students were excited about their engineering lessons, discussing them when other subjects were being taught.

Fairview

Teachers at Fairview discussed improvement in skills like teamwork as well as student enthusiasm for engineering activities. For example, Brandy discussed that her students were excited to have her read a story in class that would introduce a new engineering design problem.

> Brandy, year one: *They liked story. They were very excited about listening to it because they knew that the story was going to reveal to us what our next design challenge was going to be about.*

Joe described that his students responded well to activities that he thought they would consider boring.

> Joe, year two: *They were very excited about doing it every time we've done one, even ones that I thought were boring that we did to try to build them up to it. That's what we tried to do: We tried to start small and build up. Anytime I said we were going to do it, they were excited.*

Camille discussed that students in different grade levels had shared with each other about engineering lessons and that her students were excited before they began the lessons.

> Camille, focus group: *When we talk about what kinds of projects we are going to, the children have heard about it from the other second graders and they're enthusiastic and ready to listen and ready to participate and excited about it.*

Eastwood

All of the teachers at Eastwood described student enthusiasm for engineering. Some discussed increased learning in engineering as well as science and math. Bailey states that she believed the lessons provided the students with an in-depth experience of engineering.

> Bailey, year one: *You know, this is much more in-depth and much more interesting to the kids I think. I think they got a lot more out of this than last year what my kids got out of what I taught from the book.*

Matt discussed that his students were engaged in the lessons.

> Matt, year one: *They were more hands on and more engaged really is the word I'm looking for.*

Haley described students as enthusiastic to have more engineering lessons.

> Haley, focus group: *Sometimes I'll see them in the hall, and they say when are you coming back to do engineering.*

Instability

During the interviews and focus group, teachers from Eastwood discussed changes taking place in their building related to curriculum and teaching assignments. They described uncertainty about who will be teaching what grades or subjects from year to year. In addition, they described not having control of the curricula used in their classrooms. For example, at the end of the second year, Matt mentions moving to first grade, a grade that does not integrate engineering.

> Matt, year two: *They put me in first (grade). Subject: Math, science, social studies.*

> Hailey, focus group: *And that's another thing, we are teachers. From year to year it changes, we don't always have the same teachers teaching the same grades, and like last year we had four fourth grade teachers, so we had a science teacher this year, well we have three English and one bilingual.*

What were the changes in students' science, technology, and engineering knowledge?

In the first school year, students in second grade at Eastwood experienced greater gains on the SKTs than those at Fairview. Third and fourth grade students at Fairview experienced larger gains on the SKTs than those at Eastwood. In the second school year, students in all three grades at Fairview experienced greater learning gains than those at Eastwood. For both years, the post-test scores for all grades, except Eastwood's fourth grade in the second year, were higher at Fairview. Table 6 provides the means and standard deviations for pre- and post-tests, and mean change for each year by classroom. In addition, the number of lessons implemented in each classroom is shown to aid in interpretation between student exposure to lessons and their learning outcomes.

What were changes in students' engineering identity development?

In the first school year, students at both Eastwood and Fairview experienced gains in their attitudes towards engineering, as measured by the *Engineering Career/Aspiration* factor of the EIDS. Students in both schools experienced minimal gains in the academic identity factor. In the 2009–2010 school year, students at Eastwood experienced a slight decrease in their mean scores of the *Engineering Career/Aspiration* whereas students at Fairview experienced gains on average. Table 7 shows the descriptive statistics, including pre- and post-test means, and standard deviations.

The results of the paired sample t-test indicate that on average for the two years, Fairview students ($n = 132$) experienced significantly greater scores on the Engineering Career factor after receiving engineering instruction ($M = 27.77$, $SD = 0.31$), than prior ($M = 25.15$, $SD = 0.33$) with a low effect size, $t(116) = -6.43$, $p < 0.001$, $r = 0.20$. Although students at Eastwood in the second year did not show gains, the results of the paired sample t-test indicate that on average for the 2 years, students ($n = 44$) experienced significantly greater scores on the Engineering Career factor after receiving engineering instruction ($M = 26.50$, $SD = 0.49$) than prior ($M = 24.62$, $SD = 0.58$) with a low effect size, $t(42) = -2.54$, $p < 0.01$, $p < 0.05$, $r = 0.23$.

Discussion

In this study, teachers at both schools were within the same district that approved the integration of engineering into elementary classes, attended the same academies, and had the same opportunities for ongoing professional development. However, there were

Table 7 Student scores on the engineering identity development scale (EIDS) by school

School	Construct	2008–2009					2009–2010				
		N	M_{pre}	SD_{pre}	M_{post}	SD_{post}	N	M_{pre}	SD_{pre}	M_{post}	SD_{post}
Eastwood	Academic	23	12.78	1.24	13.30	2.09	24	12.20	1.72	11.95	1.49
	Engineering Career	23	23.30	3.25	27.09	3.51	21	26.33	3.38	26.09	2.81
Fairview	Academic	46	12.78	1.665	12.98	1.69	93	12.73	1.58	12.22	1.90
	Engineering Career	46	24.73	3.54	28.20	2.83	86	25.85	3.68	27.72	3.49

apparent contextual differences that were associated with each school's potential for sustainability. The findings from each school are synthesized below.

Teachers at Fairview were very enthusiastic about integrating engineering and technology lessons in their school and had two main supportive factors that contributed to their sustainability of the new curriculum. First, teachers at Fairview describe the school community, in terms of administration and peers, as highly supportive of engineering in elementary classes. Teachers, particularly in their first year of the professional development, prepared for and implemented the engineering lessons in a collaborative manner. They assisted teacher learning, co-teaching until each teacher was comfortable implementing the lessons. In addition, they went beyond the curricula given and found their own engineering resources to bring into the classroom and ways to involve local engineers. When discussing how to expand implementation of engineering, teachers recognized the importance of principal support, peer involvement, and reaching out to the wider community by involving parents in the curricular changes. Second, while they discussed time constraints both in the preparation and implementation of lessons, they also discussed finding creative ways to integrate engineering into other subjects as a way of meeting district curriculum standards. For example, they discussed engineering as promoting higher level skills, such as problem-solving, that would be on standardized tests, and found ways to capitalize on those in other subject areas, such as language arts and social studies. The quantitative results support the teachers' perceptions that their students experienced learning gains in science, engineering, and technology, as well as higher understanding about the work of engineers and aspirations towards engineering.

Although teachers at Eastwood discussed the engineering design and technology lessons very positively, there were contextual factors that posed additional barriers to their ability to create long-term curricular reform in their school. First, the original group that had planned to participate in the project was decreased from five to three, leaving teachers with fewer opportunities for in-school collaboration and support. They prepared for and implemented the lessons alone. Second, the departmentalized school structure at Eastwood posed a barrier to the integration of engineering design and technology into subjects other than science and math because teachers were specialized by subject instead of teaching the same students all subjects. From this context, it is also understandable that they did not discuss initiating additional engineering or technology activities in non-STEM subjects. Third, the connection between what students learn through engineering design and technology and other curricular standards was not clear to the teachers. They discussed engineering as conflicting with the new district-level standards rather than being supportive of the learning goals. They discussed the possibility of further integration into other subjects and awareness that engineering could be supportive of other learning objectives, but they were unsure of how to make those connections despite district-level work to map the engineering and technology curriculum to science standards. They also did not discuss the potential that engineering had to help students develop the skills that standardized tests are designed to measure. Fourth, teachers perceived the expectation from their principal to prioritize standardized testing preparation above the engineering lessons. This is perhaps best understood at the student demographic level; Eastwood has a very large population of students that are native Hispanic English language learners, who historically do not perform as well on standardized tests. Given this context, it is understandable that the principal would expect teachers to place high emphasis on the curriculum assessed through standardized testing. The students experienced gains in engineering, science, and technology knowledge in both years, but students' understanding of the work of engineers and aspirations towards engineering only significantly improved in the first year of implementation. The lack of significant gain in the second year might be related to teachers' perception that the lessons were a low priority for the school. In addition, when asked what factors would allow for increased engineering integration in their school during the 2010 interviews, teachers at Eastwood were unsure of how they could increase engineering at their school.

Conclusion

The purpose of this research was to study the contexts of two schools that participated in the same professional development for engineering in elementary schools, but had different outcomes in terms of lasting curricular reform. Each school had variation between teachers in terms of the number of lessons teachers actually implemented, similar to Guskey's (2003) discussion that often within school variation is greater than between school variation. Yet there are three contextual areas that were found quite different between the schools as a whole.

Teacher perceptions of administrative support

Teachers at Fairview, the sustaining school, describe their principal as being very enthusiastic about engineering, whereas teachers at Eastwood describe their principal as having competing priorities with the integration of engineering and technology. This finding is consistent with literature that administrators can either hinder or sustain reform efforts (Roehrig et al. 2007). In addition, while district support for the curriculum is important, it may not translate automatically to principal support, as was the case in this study. In addition to getting buy-in from the district-level administration, it is important for principals to be aware of the potential learning benefits that are in alignment with the broader curriculum goals.

Teacher community around the new curriculum

Similar to sustained curriculum reform found by others (Roehrig et al. 2007; Villegas-Reimers 2003), at Fairview, teacher collaboration and group support helped foster a school-wide enthusiasm for engineering and technology. Implementing hands-on, open-ended design projects with elementary students and working in teams, requires a very different pedagogy than what many elementary teachers have experience with. Having colleagues to share in the experience and provide support through co-teaching and discussion proved to be very beneficial for teachers at Fairview.

Teacher perceptions of the alignment of the lessons with district curriculum standards

Although both schools were affected by new district curriculum standards, teachers at Fairview found ways to integrate engineering in support of those standards. This finding further highlights Archibald et al.'s (2011) recommendation that professional development efforts clearly match to curriculum standards for the school. The administration at the district level communicated support of engineering and an understanding that engineering design could be used to support the district cuuriculum learning objectives, but this understanding did not transfer down to each school involved in the professional development project during these years. In subsequent years, this Institute worked with a district curriculum specialist to ensure that the link between the engineering lessons and district standards was clear to administrators and teachers. Yet, Eastwood chose to discontinue from the professional development program.

Limitations

As with all research, this case comparison has limitations. These schools are not meant to be representative of all elementary schools. Rather, this is a deeper look into their contextual factors that may provide insight into how professional development for engineering can be more successful in the long-term. Although schools were asked to commit at least four teachers to participate, Eastwood only allowed three teachers to implement the engineering lessons. This limited the number of teachers and their classrooms available to be studied. In addition, direct observation would shed additional light on how teachers implemented the lessons. The small number of student participants within each classroom may not be representative of their class mean scores. Further research is needed to understand what type of learning outcomes specific to engineering can be expected from elementary students.

While we found that teachers' perception of administrative support was one of the key factors to sustain engineering curricula in school, we did not have data directly from administrators. At the time of the interviews, we did not yet know which schools would sustain and which would drop-out. This study focuses on teachers' perceptions and experiences with implementing engineering lessons. Therefore, results about administrative support must be interpreted in light of teacher perception, which may or may not be the same as their administrators' perceptions. However, whether or not their administrators felt they were supportive, our results indicate that teachers within the same school clearly had similar perceptions about administrative support, which is an important finding. Future research should consider the relationship between administrators' perception of giving support and teachers' perception of administrative support received in implementing engineering.

Implications and future research

The integration of engineering into elementary classrooms is in its infancy, bringing with it a need to understand how to best prepare teachers for this transition. Engineering as a subject in elementary classrooms is not only new to teachers, but also to principals and other administrators. Because of this newness, not all administrators can be expected to instantly see the value of engineering being taught to their students. There is a considerable time commitment for teachers to understand engineering concepts and be prepared to teach. Administrators may see this commitment as competing with other, more pressing needs they are able to recognize within their school. Future efforts in engineering professional development should consider having an administrator session to inform administrators about the potential of engineering to increase students' mathematics and science learning. In addition, trainers could elicit a conversation with administrators about their contextual concerns with integrating engineering. These concerns could be used to inform future research on engineering in those contexts. For example, research is needed on how English language learners engage in engineering activities and if engineering is supportive of their learning in other subject matters.

In the current testing culture, administrators have to be focused on how the classroom time is being used to help students be successful on the standardized tests. Efforts are currently underway to develop standardized testing of engineering skills (National Assessment Governing Board 2013). As more states include engineering standards into their standardized testing, the connection between engineering lessons and curriculum objectives will need to be very clear for teachers and administrators.

The pedagogy used in engineering activities may be quite different than how elementary teachers have previously managed their classrooms. Student teamwork and the open-ended solutions (e.g., no single "right" answer) may provide additional challenges to teachers as they begin implementing the lessons. In addition, in the time between discussing the lessons in the academy or workshop and actually implementing in the classroom, teachers may not retain what was discussed. It is for these reasons that professional development efforts should explicitly include asking teachers to schedule out and think through logistics of how and when they are going to collaborate. Time should be devoted to addressing unique contextual factors that may support or hinder this.

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