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Computing and Engineering in Elementary School: The Effect of Year-long Training on Elementary Teacher Self-efficacy and Beliefs About Teaching Computing and Engineering

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Abstract

STEM, the integration of Science, Technology, Engineering, and Mathematics is increasingly being promoted in elementary education. However, elementary educators are largely untrained in the 21st century skills of computing (a subset of technology) and engineering. The purpose of this study was to better understand elementary teachers' self-efficacy for and beliefs about teaching computing and engineering. An entire faculty of a US-based elementary school participated in a year-long series of weekly professional development trainings in computing and engineering. Researchers collected quantitative data through a survey designed to assess teachers' self-efficacy and beliefs towards the integration of computing and engineering and compared responses with a demographically similar Title I school in the same city. Additional qualitative data was collected through semi-structured interviews and documented observations. Researchers found that between the two schools, self-efficacy and beliefs toward computing and engineering were likely influenced by professional development ($p < .05$). Through interviews, teachers attributed changes in self-efficacy and beliefs to the trainings. Although all teachers reported higher beliefs about the importance of computing and engineering, their self-efficacy for teaching these varied widely. A grounded theoretical analysis revealed this difference was likely attributed to each teacher's level of implementation, background, and willingness to experiment. We discuss how these factors may affect the professional development of elementary educators in preparing them to teach computing and engineering-related topics.

Keywords: Professional development; elementary education; STEM; computing; engineering; STEM integration

1. Introduction

Historically, efforts to promote STEM in K-8 (i.e., the integration of Science, Technology, Engineering, and Mathematics) have emphasized science and mathematics, while less attention has been paid to Technology and Engineering. However, this support is changing for both Technology and Engineering. There appear to be two qualitatively different but important types of changes occurring for the promotion of technology and engineering during a student's formative education. Namely, changes are occurring through structural support and through increased resources.

Most *structural support* for technology and engineering has occurred through policy changes that require the teaching of these subjects. For example, the Next-Generation Science Standards (NGSS), which are beginning to take effect in schools across the United States, indicate that engineering design, or the process that engineers follow when solving problems, will be "elevated to the same level as scientific inquiry" (NGSS, 2013, p. 1) at all levels of education. Meanwhile, computing—a subset of Technology—is gaining increasing attention as an essential 21st-century skill. In 2014, England began including computing as a core competency, requiring all students to begin learning computing in kindergarten. Finland has since followed suit, with its government declaring that all teachers must integrate computing across the curriculum starting in the first year of a child's schooling (Opetushallitus, 2014). South Korea recently made a similar requirement. Scotland has drafted a curriculum map for including computing in its core and plans to have it take effect by the 2017 school year. Australia's new digital technologies educational standard requires that children learn computational thinking as early as kindergarten. What's more, Balanskat & Engelhart (2014) reported that computing is now compulsory, or will be by 2020, in 20 different European countries. In February, 2016, Rhode Island became the first U.S. state to commit to teaching computing to all students in K-12. Indeed, President Obama's recent proposal to spend $4 billion dollars on bringing computing to all students indicates a shift in priorities toward the inclusion of computing in core educational practices.

Resource changes refer to an increased access to curricula and materials that help teach computing and engineering (C&E). The availability of toys, tools, and curriculum to teach computing to children has been explosive. Code.org has provided a rallying cry for teaching kids to code. It has become a hub for other industry products intended to teach children to code. Through this hub, children can learn to code in visual languages, text-based languages, and a variety of different robotics. Products such as Lego Mindstorms, Scratch, Tynker, Wonder Workshop, Sparkfun, Microduino, Raspberry Pi, Code Combat, CodeAvengers, LittleBits, mCookie, Hopscotch, Technology Will Save Us, Snap Circuits, Makey Makey, Leapfrog Arduino and many, many more are all aimed at helping kids learn to code or engineer (or both). The ability to 3D print their designs, to control wearable technology or to solve everyday problems through computing and engineering allows this generation to learn to control and command their increasingly computationally-driven world. Just as radio, television, and video games opened up new possibilities and creations, it seems that this generation's push to create is going to be through computing and engineering (C&E).

While both structure and resources to teach C&E to children have increased drastically, *teacher training* is lacking. This newfound emphasis on C&E in earlier grades means that teachers need to learn how to integrate these into an already-packed schedule. Elementary school teachers, trained as generalists, have had years of training in both the content and pedagogy of mathematics and science, but they generally have had neither content nor pedagogy training in either computing or engineering (Fiztgerald & Cunningham, 2013). Thus, current educational systems hoping to teach these important 21st-century skills are faced with a critical question: How can they best prepare primary teachers to be both competent and confident instructors of C&E? In this paper, we report on the first-year efforts of one elementary school to answer this question.

2. Literature Review

In order to understand how to train elementary teachers to teach engineering and computing (C&E), we provide a brief overview of efforts to accomplish this goal. We first discuss efforts to improve elementary teachers' computing skills, followed by a brief analysis of efforts to incorporate engineering into elementary education. We then describe how these informed our own approach to teach an entire elementary school faculty to incorporate C&E into their teaching.

2.1 Computing

Efforts to teach computing to younger children reaches back to the early 1960s. The purpose was often to promote computing in the service of learning to think algorithmically and to help students become better problem solvers (Noss, 1986). These efforts gained momentum in the 1980s with the publication of Seymor Papert's book, Mindstorms. Many subsequent efforts to teach computing used Logo, the imperative coding language promoted by Papert. Studies on Logo often involved teaching elementary and middle-school aged children to code geometric figures. While early research on the use of Logo in elementary education produced mixed results (Kurland, Pea, Clement, & Mawby, 1986; Pea & Kurland, 1984), subsequent research has consistently demonstrated a positive effect of learning to code. Liao and Bright (1991) conducted a meta-analysis of 89 different studies that compared cognitive outcomes from students who had learned to code with those who had not. Out of 432 comparisons, results were positive 65% of the time, with a mean effect size of .41. In another review, McCoy (1996) found that teaching Logo was especially effective for children in early elementary, resulting in greater understanding of geometric reasoning and the concept of variables. Clements, Battista, and Sarama (2002) conducted a series of studies with students at the K-6 level and repeatedly found positive results. Namely, that students who learned Logo outperformed their counterparts on their understanding of shape, measurement, symmetry and arithmetic. Thus, repeated results over several decades demonstrate a decidedly positive effect of teaching young children to think computationally.

While there are literally hundreds of studies that examine the effect of learning to code on student outcomes, there is relatively little research on how to train elementary school teachers to teach computing. With recent calls to include coding in elementary and secondary curricula, however, studies that examine how to prepare teachers to integrate coding are beginning to emerge. These have examined both in-service teachers (Blum & Cortina, 2007; Prieto-Rodriguez & Berretta, 2014) as well as preservice teachers (Sadik, Ottenbreit-Leftwich, & Nadiruzzaman, in press; Yadav et al., 2014). We briefly describe these studies and what we have learned from elementary teachers learning about computational thinking.

In a recent study, preservice elementary education teachers spent one week of a required educational psychology course learning about computational thinking (Yadav, Gretter, Good, McLean, *in press*). The authors found that preservice teachers could develop a reasonable understanding of what computational thinking is during this time and even express ideas of how to integrate it into their teaching. However, the short timeframe in which they studied computational thinking was insufficient to develop any sort of expertise or ability to teach the topic. The researchers concluded that, "we need to develop ways to embed computational thinking concepts and practices across disciplines both with and without the programming context to benefit students with varied interests." In short, teachers need multiple exposures to computing in varied contexts so that they can understand how computational thinking (Wing, 2006) can improve students' problem-solving skills regardless of domain.

In another study, Sadik et al. (*in press*) engaged preservice teachers enrolled in a course designed to grant them a computing certificate ($N = 12$) in a number of online and unplugged activities throughout the semester, culminating in a "*2 hours of code*" project that these preservice teachers then taught to 5th-grade students ($N = 120$). Preservice teachers first learned about computational thinking by completing activities on Code.org and Scratch. They then examined a 5th-grade curriculum for alignment with computational thinking concepts and proposed possible lessons that might benefit from a computational thinking approach. Practicing 5th-grade teachers provided feedback on the viability of these approaches and preservice teachers then chose which ideas they would develop into complete lessons. The culminating activity required that they teach these lessons to a classroom of 5th-graders. Researchers analyzed pre and post-reflection logs, video proposals and teacher feedback to examine preservice teachers' conceptions of computational thinking. While the research indicated that preservice teachers generally increased in their positive attitudes toward computational thinking, they conflated it with algorithmic thinking specifically. This notion mirrors Yadav et al.'s (in press) findings in that preservice teachers equated all of computational thinking with the one aspect that they focused on the greatest. Thus, while Sadik et al.'s study provides a clear example of how to teach computational thinking in early teacher training, it also demonstrates that a short exposure to it results in a nascent, though incomplete, understanding of what computational thinking entails.

2.2 Engineering

Thousands of hours have been invested in training educators of primary education to help implement engineering into their curriculum (Engineering is Elementary, n.d.). One of the frontrunners of this training is the Engineering is Elementary (EiE) curriculum created by the Boston Museum of Science. EiE has been venturing into the growth of engineering in grades K-8 for ten years and continues to strive to improve its program. There are 20 units to choose from in the EiE curriculum. Each unit in EiE begins with a lesson on what engineering and technology is. The objective of this lesson is to address and eliminate misunderstandings of what technology and engineering actually entail. Additionally, EiE teaches the Engineering Design Process (EDP) at the beginning of each unit. The EDP helps develop the creativity of the children with appropriate constraints and direction.

In striving to implement engineering in elementary schools, EiE has developed daylong workshops for professional development. In these workshops, teachers were expected to participate as a student. Teachers were assessed (both formatively and summatively) as their students would be. Each professional development was focused on one of the units of the school's choice. In addition to the objectives set in EiE, teachers had the option to add any goals that they may have for the workshop. A survey was distributed after each workshop. These surveys showed that although teachers felt that they had an increased understanding of engineering from this experience, they still felt unprepared for implementation. Because of this low self-efficacy in implementation, EiE called for further suggestions for improvements of professional developments and workshops to help address the development of teachers' low self-efficacy in implementation (Sargianis, Yan, & Cunningham, 2012).

In response to this call, members of EiE continued to develop professional developments through Bridging Engineering, Science, and Technology (BEST) for elementary educators. BEST strives to build a solid foundation for future technologists and engineers. These practices are meant to help instill strong beliefs in teachers to improve the implementation of technology and engineering at primary levels. Through professional developments and workshops, they were able to work with faculty and elementary education students to improve attitudes and competence towards engineering education. BEST first focused on preparing college faculty at each school through professional developments, who then took the experiences to their students (i.e., preservice teachers). Pulling from six different colleges, 183 preservice teachers participated in a survey that was administered in the Fall of 2010 (Fitzgerald & Cunningham 2013). Pre and post tests were administered to help determine their knowledge of engineering principles compared to responses by engineers by the Decision Science Research Associates. From these responses, they found that participants' competence and understanding of engineering principles increased, as well as their attitudes towards their own abilities, expectations, and awareness.

However, the following semester (i.e., spring semester 2011), when the researchers surveyed 277 students from six colleges (one school being different from the last), there were little changes from pre- to post-test in the competence. In the pre-test, the participants differed by 96% from experts, decreasing only to 94% in the post-test. In addition to the competence, eleven statements were added regarding knowledge of and attitude toward engineering that the preservice teachers took before and after participating in the training. Despite the lack of changes in competence, there was a notable increase in attitude toward engineering. The BEST group remained perplexed at what might have caused this lack of change in competence, but positive change in attitude. One important interpretation of these results is that teachers' self-efficacy for a subject and their belief in its importance, may operate independently as in other teaching domains (Velthuis et al., 2014). In other words, an increase in positive attitudes toward a subject does not necessarily cause an increase in teacher competence for that subject.

Facilitators of EiE continued to perform their own research for professional development for in-service teachers. To improve understanding and attitudes of the implementation of engineering, the researchers emphasized the integration of other subjects with science and math to make a full connection into the STEM world. A survey was distributed three months after the workshop to see the impact of the experience in the classroom. Of the 21 attendees, 13 responded to the distributed survey. Researchers found that the workshop had a positive impact on the majority of the teachers. Three major findings emerged: (a) some teachers were already implementing an integrated curriculum; (b) they lacked engineering resources; or (c) they did not feel supported by administration. Open-ended responses supported the value of engaging in hands-on activities and the increased confidence in teaching math in science that also came as a result of participation in the workshop (Morgan, Fitzgerald, & Hertel, 2014).

These recent efforts demonstrate training in C&E that are extended to primary educators. Not only do teachers need to first be taught the material, but there remains the need for teachers to receive and feel support to be comfortable and confident in teaching the material. In our study, we used the Scratch program (http://scratch.mit.edu) with code.org curriculum together with Engineering is Elementary over the course of a school year to teach teachers how to use computing and engineering in their lessons. In the following section, we report on our methods to better understand how this training affected elementary teachers' self-efficacy for and beliefs about C&E, specifically.

3. Methods

We employed a mixed methods research design to study the efficacy and beliefs of elementary school teachers in a Title I school. Teachers participated in a year-long series of weekly professional development trainings designed to influence their self-efficacy and beliefs for teaching computing and engineering (C&E) in their classes. Researchers collected quantitative data from the study school and a comparison school with similar student demographics through a survey designed to assess teachers' self-efficacy and beliefs toward integrating C&E. Qualitative data included semi-structured interviews and documented observations. The remainder of this section will address the study population, context, data collection and analysis.

3.1 Population

Study participants consisted of elementary school teachers teaching grades K-6 in a Title I school. All 27 teachers at the school participated in the weekly professional development trainings. Table 1 indicates the average years teaching and the number of teachers for each grade. The student population consisted of 613 students of which 52.2% were racial/ethnic minorities, 19.58% English Language Learners, 80.1% low socio-economic status, and 24.94% were students with disabilities (note this school houses both the designated special needs students, as well as the school district's gifted program for students in 4-6th grades) . The comparative school consisted of 453 students, of which 60.26% were racial/ethnic minorities, 36.87% English Language Learners, 83.44% low socio-economic status, and 13.47% students with disabilities. Teacher experience and grade taught is broken down in Table 1.

Table 1. Teacher Demographics at the Study School

Grade Level	Mean Years Teaching		Count	
	Study School	Comparison School	Study School	Comparison School
Kindergarten	6	2	3	4
First	9	14	2	3
Second	2	16	3	3
Third	4	7	2	3
Fourth	12	13	2	2
Fifth	18	8	3	4
Sixth	12	2	3	2
Special Ed	11	7	9	4
	Mean: 9.25 years	Mean: 8.63 years	Total: 27 teachers	Total: 25 teachers

3.2 Context

Researchers met with school leaders prior to the beginning of the 2014-2015 school year to establish a detailed implementation plan for the integration of computing and engineering into the K-6 curriculum. This four year implementation plan outlined yearly implementation benchmarks and critical research objectives. The focus of the present study was the research objectives for year one.

Teacher development was the sole focus of year one implementation. Teachers were not required to integrate computing or engineering into their curriculum. Rather, year one implementation benchmarks included the development of teachers' computing and engineering core instructional competencies, self-efficacy, and beliefs. The overarching goal for year one was to foster in teachers: (a) a positive view of their ability to integrate C&E, (b) positive beliefs about the relevancy of C&E to their students, and (c) core skills in C&E instruction. Year one research objectives were to identify factors influencing the development of teachers' self-efficacy and beliefs toward C&E instruction.

Researchers conducted weekly professional development trainings during the last 45 minutes of grade level collaboration. Professional development consisted of three distinct phases, which emphasized (1) the establishment of a collective school vision for computing and engineering instruction, (2) the development of engineering core competencies, and (3) the development of computing core competencies. A collective school vision was established through a series of faculty trainings. These trainings consisted of engineering design challenges and *unplugged* computing lessons (Table 2). In addition, teachers participated in small-group trainings, which included Engineering is Elementary (http://www.eie.org/eie-curriculum) curriculum units and computing activities (Table 2). Each training lasted for six weeks, after which groups rotated and began collectively studying another topic. All groups engaged with two Engineering is Elementary units and one computing unit. Computing units began with teachers completing the 20 "beyond an hour" of code activities at code.org and ended with teachers creating their own content in the Scratch programming environment (see http://scratch.mit.edu).

Table 2. Engineering units and computing activities

Grade Level	EiE Curriculum Unit	Computing Activities	Faculty Trainings
Kindergarten & Special Ed	1. *Sounds Like Fun* 2. *Thinking Inside the Box*	1. Code.org hour of code 2. Code.org beyond an hour 3. Coding in Scratch	1. Modified paper bridges[1] 2. Modified paper pylons[2] 3. Modified human robot[3]
First & Second	1. *Simple Machines* 2. *Play Dough Process*		
Third & Fourth	1. *Windmills & Weather* 2. *Insects & Plants*		
Fifth & Sixth	1. *Lighten Up* 2. *Magnetism*		

3.3 Quantitative Data Collection

Researchers collected quantitative data through a survey administered to teachers at both the study school (n = 27) and comparison school (n = 25). Teachers were compensated with a $15 Amazon gift card for completing the survey. The survey was a modified version of the the Friday Institute for Educational Innovation's *Teacher Efficacy and Attitudes Toward STEM Survey* (2012) for elementary teachers. Responses were reported using one of two Likert type scales. The first Likert bipolar scale had anchors of *Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree.* The second Likert unipolar scale had anchors of *Never, Occasionally, About half the time, Usually, Every time*. The modified survey measured the following constructs: Science Teaching, Science Teaching Outcome Expectancy, Mathematics Teaching, Student Technology Use, Elementary STEM Instruction, STEM Career Awareness, Computing Teaching Beliefs, Computing Self-efficacy, Engineering Teaching Beliefs, and Engineering Self-efficacy. Table 3 lists the added survey questions for the self-efficacy and beliefs constructs. We did not modify questions regarding Science and Math.

Table 3. Modified/Added Items Added to Measure Engineering and Computing Self-Efficacy and Beliefs

Construct	Item
Engineering Beliefs	1. I am willing to take the time to plan engineering lessons for my class 2. It is important for my students to understand the engineering design process 3. My students are capable of learning core concepts from "real-world" engineering design problems 4. Implementing engineering design problems adds value to my classroom 5. Engineering design problems are more than fun activities
Engineering Self-efficacy	1. These variables seek to measure the self-reported competence of participants about engineering teaching. 2. I can identify which step in the engineering design process I am in when problem solving 3. I see examples of how engineering influences my daily activities. 4. I can see how to integrate engineering into other subject areas. 5. I can integrate core standards into an engineering design problem
Computing	1. Knowledge of coding can be helpful to improve most careers

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[1] —http://www.scientificamerican.com/article/paper-bridges/

[2] —http://pbskids.org/designsquad/parentseducators/resources/paper_table.html

[3] —https://www.teachengineering.org/activities/view/umo_robotsandhumans_act1

Beliefs	2. Knowledge of coding can be helpful to improve most careers
Computing Self-efficacy	1. I can explain basic programming concepts to children (e.g., algorithms, loops, conditionals, functions) 2. I can plan out the logic for a computer program even if I don't know the specific programming language 3. I know where to find the resources to help students learn to code. 4. I can find applications for coding that are relevant for students. 5. I can integrate coding into my current curriculum. 6. I can help students debug their code.

3.4 Quantitative Data Analysis

The quantitative data analysis compared the survey response data from both the study and comparison schools. Independent-samples t-tests were used to determine the extent to which schools differed in terms of each survey construct. The non-parametric Mann-Whitney U test was used in place of the independent-samples t-tests when data had issues of skewness, kurtosis, or significant homogeneity of variances. Statistical significance was set at the $\alpha =$. 05 level. We hypothesized that teachers' attitudes toward science and math would be similar at each school, while their beliefs about engineering and computing would differ.

3.5 Qualitative Analysis

A question on the survey asked teachers at the study school if they would be willing to participate in a follow-up interview. Thirteen of 27 survey respondents agreed to this follow-up interview. The purpose of the interview was to probe deeper about teachers' reasons behind their provided survey responses. In addition, we wanted to provide teachers with an opportunity to tell any stories behind their own beliefs about, experiences with, or confidence in teaching computing or engineering in their classrooms. We therefore constructed semi-structured interviews with an emphasis on encouraging narrative responses. Interviews lasted roughly 20-40 minutes each. All interviews were transcribed verbatim.

We used a grounded theoretical approach to analyze interview data. Grounded theory comprises a series of methods to generate descriptions and explanations grounded in participants' experiences. A grounded theoretical approach seeks to go beyond description and includes explanation and even prediction. As its founders stated, "theory must fit the situation being researched, and work when put into use" (Glaser & Strauss, 1967, p. 3). The hope is that the produced theory can be applied to similar situations in the future to better understand participant's experiences. While multiple approaches to grounded theory analyses have emerged over the years, we followed AUTHOR's (2012) approach, wherein we approached the data without *a priori* categorization of any data.

Researchers first analyzed teacher statements by summarizing each meaningful statement descriptively. Where appropriate, researchers coded a statement with multiple descriptions, using the Dedoose qualitative data analysis tool. For example, we coded the statement, "I knew nothing about [STEM] and it's been really fun" both as *beginning knowledge* (because it indicates where the teacher was starting from) and *emotional response* (because of the reference to "fun"). We triangulated these with teachers' survey responses through constant comparison. Constant comparison involves measuring new descriptions against each other to ensure that what emerges as a common categorization is consistent across the different data, grounding descriptions in the gathered evidence. We maintained a codebook with common definitions for each code, modifying these as we constantly compared data.

Once initial categorizations emerged, we articulated the properties of each code. Additionally, we looked for the variance within each sub-category. For example, the earlier statement that was coded as an emotional response demonstrates one type of emotion (i.e., excitement). Other emotional responses, such as concern or trepidation, would also fall under the emotional response category but were different variants of emotion. This further specification led us to restructure some of our categorizations as we compared our new definitions and realized that some statements that we had identified as separate categories were variants of the same categorization.

Throughout this coding process, we maintained memos where we began to notice odd or seemingly important patterns or trends in the data. “Patterns are formed when groups of properties align themselves along various dimensions” (Strauss & Corbin, 1990, p. 117). Memos served as a mechanism to connect themes or highlight curious findings that could span multiple categories of codes.

Finally, we identified underlying themes that might tie categorizations together. For example, while “beliefs” and “self-efficacy” were clearly different categories, we asked whether there appeared to be any relationship where one might be influencing the other. Strauss and Corbin (1990) contend that patterns emerge when categorizations align across several dimensions. Furthermore, while coding qualitative data descriptively is a simple task, identifying themes involves discovering the interplay among the many different codes.

Themes that emerged across all codes and participants dealt with: (a) prior experience, (b) level of implementation, (c) willingness to experiment, (d) self-efficacy, and (e) beliefs about C&E. Once we identified these as the driving force behind participant experiences, we created a separate user profile outlining teachers’ level on each of these constructs. This resulted in individual profiles for each participant and allowed us to align their experiences and attitudes to a 10-point scale in each area that emerged through interview analysis. Additionally, we conducted a negative case analysis to verify if our coding scheme applied to all teachers. In the following section, we discuss the resulting themes, how we calculated the reported scales, resultant participant profiles and how these may affect the way we view teacher professional development for designing future computing and engineering experiences for teachers.

4. Findings and Discussion

The analysis of the similarities and differences between the study school and comparison school survey responses helped to clarify the collective influence of weekly professional development trainings on teachers’ self-efficacy and beliefs toward C&E. In contrast, teacher interviews helped to clarify the individual changes in self-efficacy and beliefs and the impact of weekly professional development on these changes. This section will first discuss the similarities and differences between the study school and comparison school in terms of survey responses, after which we discuss the individual differences between a subset of teachers at the study school.

The overall results from the analysis of survey results showed that the study school and the comparison school were both similar and different depending on the particular construct being measured. The similarities and differences in survey responses help to better understand the influence of weekly professional development trainings on teachers’ self-efficacy and beliefs toward C&E. Table 4 reports the statistical results from comparing the study school and comparison school in terms of the survey constructs.

Table 4. Results of Comparison School and Study School by Construct

Construct Name	**Statistical Test**	**df / median**	**T / U**	**p-value**
Science Teaching	t-test	$df = 47.92$	$t = 1.27$	$p > .208$
Science Teaching Outcome	t-test	$df = 47.66$	$t = -.98$	$p > .331$
Mathematics Teaching	t-test	$df = 44.16$	$t = .80$	$p > .426$
Student Technology Use	Mann-Whitney U	$Mdn_{SS} = 1.75$ $Mdn_{CS} = 2.13$	$U = 401.5$	$p > .151$
Elementary STEM Instruction	t-test	$df = 48.87$	$t = -.26$	$p > .799$
STEM Career Awareness	t-test	$df = 47.46$	$t = -3.10$	$p < .004$**
Computing	Mann-	$Mdn_{SS} = 3.5$	$U = 220.5$	$p < .050$*

Construct Name	**Statistical Test**	**df / median**	**T / U**	**p-value**
Teaching Beliefs	Whitney U	$Mdn_{CS} = 3$		
Computing Self-efficacy	t-test	$df = 48.70$	$t = -3.66$	$p < .001$**
Engineering Teaching Beliefs	Mann-Whitney U	$Mdn_{SS} = 4.2$ $Mdn_{CS} = 3.4$	$U = 90$	$p < .001$**
Engineering Self-efficacy	t-test	$df = 45.6$	$t = -5.88$	$p < .001$**
Days Teaching Engineering or Computing	Mann-Whitney U	$Mdn_{SS} = 5$ $Mdn_{CS} = 0$	$U = 167$	$p < .001$**

Subscripts: SS = Study School; CS = Comparison School
* $p \le .05$, ** $p \le .01$, and *** $p \le .001$

Concepts related to the four survey constructs of *Science Teaching*, *Science Teaching Outcome*, *Mathematics Teaching*, and *Student Technology Use* were not a direct emphasis of the weekly professional development for teachers at the study school. As shown in Table 4, there was no statistically significant difference between the study school and the comparison school in terms of these four constructs. This similarity between the study school and comparison school provided additional evidence that the two schools were likely comparable. Concepts related to the six survey constructs of *Elementary STEM Instruction*, *STEM Career Awareness*, *Computing Teaching Beliefs*, *Computing Self-efficacy*, *Engineering Teaching Beliefs*, *Engineering Self-efficacy*, and *Days Teaching Engineering or Computing* were all a direct emphasis of the year-long weekly professional development for teachers at the study school. Statistical results found in Table 4 indicate that the two schools were statistically different in terms of all constructs with the exception of *Elementary STEM Instruction.* In the absence of a pre and post measure, the differences between the two schools suggests that, as a whole, teachers at the study school were likely influenced in their self-efficacy and beliefs toward C&E over the period of time in which they participated in the weekly professional development trainings. This finding was also borne out in individual teacher interviews, where teachers specifically attributed changes in self-efficacy and beliefs to the weekly trainings.

4.1 Individual Teachers

Table 5 presents pseudonyms, biographical information, and relationally assigned ratings of self-efficacy and beliefs regarding elementary STEM education that emerged through triangulation of teacher interviews and survey responses. Because ratings were based upon teacher statements, the table represents only the information for teachers who we interviewed.

Table 5. Composite Profile for Each Interviewed Teacher at Study School

					Interview			Survey		
Pseudonym	**Background**	**Years Teaching**	**Grade**	**Certifications**	**Level of Implementation**	**Efficacy Rating**	**Beliefs Rating**	**Days Spent on C&E**	**Composite C&E Self-efficacy**	**Composite C&E Beliefs**
Candace	None	33	K-6 Speech pathology aide	Speech pathology	0	0	6	0	3.54	3.55
Trisha	None	5	5		2	3	6	0	3.25	3.90
Melissa	None	3	3		3	2	6	NA	NA	NA
Hailey	Coded in high school, had some experience programming	19	6	ELL, Math, Special education	6	1	8	6	3.96	4.80
Hannah	None	4	K	ESL	0	0	6.5	5	3.38	3.40
Linda	None	9	1	Taking STEM endorsement	1	1	8	0	2.29	3.60
Jessica	None	7	1-6 Self contained special education cluster class	Special education, TESOL	0	1	7	5	2.13	3.85

Catherine	None	11	K	ESL, ECE	0	1	10	5	2.29	4.45
Wendy	Has a family made up of engineers	2	2	ESL	4	4	9	10	2.96	4.00
Hellen	Has taught STEM before, has STEM certification, worked at a STEM school, has done extra trainings	16	6 Gifted class	Administration, Gifted/Talented	8	7	9	35	4.25	4.30
Sarah	None	24	4-6 Self contained special education cluster class		1	2	8	10	3.42	4.70
Lucy	None	23	1-4 Special education extension pullout	ESL	0	2	6	0	3.13	3.10
Katie	Has a background in chemistry, self expressed pre-existing confidence for STEM	4	K Special education extension pullout		0	3	6	0	3.46	3.20

4.2 Mediating Factors

Several mediating factors emerged that appeared to explain teachers' self-professed levels of self-efficacy for or beliefs about either engineering or computing. Specifically, teacher background, implementation level, and the professional development training. In the following section, we briefly discuss how we rated each of these in order to better situate the ensuing discussion on teachers' self-efficacy and beliefs.

4.2.1 Background

As demonstrated by Table 5, the majority of elementary teachers in our study had no background in, or experience with, either computing or engineering (C&E). Those teachers who did have a background varied from taking a course in high school, to occupations of family members, to gaining certifications or degrees in a STEM-related field. In addition to the variation in background, there was variation in the degree to which these background experiences directly associated with integrating C&E in the classroom with science and math. However, teachers with STEM-related backgrounds generally demonstrated higher self-efficacy for and stronger beliefs about C&E. Even more importantly, those who had this background were more willing to implement C&E activities. While this points to the importance of providing teachers with C&E related experiences, a teacher's background itself is not something that can change once they arrive at a school. Thus, one limited recommendation to increase the likelihood of teachers engaging in C&E activities might be to seek out and hire those with stronger backgrounds in STEM areas. However, as noted in the remainder of our analysis, we found that, as influential as background might be, there were other factors that led teachers to increase their self-efficacy for and beliefs about C&E.

4.2.2 Level of Implementation

Implementation proved to be a more powerful mediator of teachers' self-efficacy for and beliefs about C&E than teachers' background. This was especially revealing due to the fact that teachers were not required to implement C&E practices in this first year of the project. Through interviews, teachers revealed varying levels of implementation, which we ranked based on risk. We defined risk as the extent to which implementing the activity might affect regular class instruction. For the sake of this analysis, risk levels were determined relative to each other. Teachers who demonstrated greater risk scored at the high end of the scale while those who did nothing scored at the low-end of the scale. Linda demonstrated a low-level of risk when she took a computing activity home and tried it out with her kindergarten-aged son. We rated this as a level 1 implementation. Anything above a level 1 indicated that the teachers attempted to incorporate a C&E activity in the classroom. Trisha (3rd grade) and Wendy (2nd grade) demonstrated a higher level of risk, as seen by their given scores of 2 and 4, by implementing C&E activities as extensions outside of or disconnected from the traditional core curriculum. This was evidenced by their comments that they "did a lot of little [engineering] activities," such as an egg drop, tinfoil boats, and building structures out of toothpicks and gumdrops. Trisha commented it was hard to see how C&E could be applied in the classroom, but noted after engaging in these extension activities that, "after doing a lesson myself, it's like, 'oh I see how this can work into my language arts...once you start doing it, you're like, oh I can see how this can work.'" Trisha's implementation was rated as a 2, while Wendy was rated at level 4.

Hellen, on the other hand, demonstrated a higher level of implementation when she spent several weeks allowing her sixth-grade students to learn to use Scratch. She then allowed those students to use Scratch for a final project (it was not required to use Scratch, as students could present the project in other forms). Eight students chose to use Scratch to present a final report on the Renaissance. Curiously, even though Hellen saw the benefit of allowing students to learn computing through Scratch, she did not have a high self-efficacy for computing herself. She confessed, "I'm not real confident with uh, I don't think I've used Scratch enough, [but] … I felt comfortable enough to introduce it to the kids, and show them some of the features and then they sort of self-taught and taught each other how to do it. So I think I just need more practice."

Prior to this professional development, Hellen reported a high self-efficacy for engineering because she had already been engaged with engineering activities at her previous school for three years. However, following this professional development, she still expressed low self-efficacy for computing. Even though Hellen reported a low self-efficacy for computing, due to her previous successes with engineering, she demonstrated a greater willingness to implement computing in the classroom, which we rated as an 8/10 on our implementation scale.

4.2.2.1 Willingness to experiment

An important disposition emerged as we interviewed different teachers. We noted that teachers who implemented C&E in the classroom described themselves as more willing to experiment with untested ideas in general (whether in STEM or in any subject area). We defined willingness to experiment as a teacher's comfort with attempting to either teach new content or new lessons in the classroom even while demonstrating a lower self-efficacy for that content matter. Teachers like Hellen were very willing to experiment, attempting higher risk activities in their classrooms, such as end-of-unit synthesis projects created entirely in Scratch. She also used engineering lessons to teach concepts in the science curriculum. Hellen did this despite originally identifying that engineering was "way out of my league," before attempting to teach it in the classroom (three years prior). She also expressed concerns regarding her own ability to code and use computing technologies.

When teachers were willing to experiment, their results were similar to Wendy's when she shared, "that the kids can do it and it can be something super simple and it's also showed me too that I can do it and I probably do it more often during my day than I really… realize I'm doing." Teachers who were willing to experiment demonstrated increases in beliefs and self-efficacy for bringing C&E into the classroom. Thus, it would seem that the disposition to experiment with new ideas often led to greater implementation. In turn, actually implementing C&E lessons (at any level) led to self-reported increases in a teachers' self-efficacy for that subject.

4.2.3 Training

Training was a mediating factor that appeared to affect both beliefs and self efficacy. There were minor shifts in self efficacy in some of the teachers that were not attributed to any background or implementation. These teachers attributed the ability to both receive direct instruction on C&E and work through lessons as students themselves to minor increases in self-efficacy. Trisha stated that prior to the training, C&E was just "another hoop ...to jump through, [and] to schedule," and that following the training, she could see how C&E could "be a writing thing ... how it really helps build classroom relationships where there is respect, [and] it's a good equalizer." Jessica stated that the teachers had a "we can make this happen" attitude after working through lessons during trainings. This sentiment was shared by the majority of the teachers whose self-efficacy improved succeeding the trainings. Linda even stated that she began "taking the STEM endorsement because of [the professional development]." The ability to receive instruction and practice lessons and activities in a structured low-risk environment was impactful on the beliefs and self-efficacy of the teachers.

4.3 Beliefs

The beliefs scale (Figure 1) represents expressions of value placed by teachers on teaching STEM in elementary years (K-6) as revealed through their interviews. The scale of beliefs is evaluated from 0, a belief that computing and engineering should not be taught in elementary years, to 10, a statement with such heavy zeal that the teacher believes it is integral to child development and elementary curriculum.

There was again a spectrum in which the teachers fell, but overall the teachers trended towards the latter half of the scale, demonstrating stronger beliefs in the importance of C&E for student development. All of the teachers expressed at least a neutral view towards teaching computing and engineering, with most giving general statements that were positive towards C&E instruction in the elementary classroom. Hannah shared that she "thinks it's a really good thing, and [she is] excited to even learn more about it." Candace shared a similarly general positive attitude towards C&E, saying, "I think I'm much more in favor of [C&E]. I mean not that I wasn't in favor of it before but I know more about it." Other teachers shared that it taught the students positive skills such as perseverance and problem solving. They also stated the importance of developing C&E technical skills due to current societal demands.

A few teachers expressed high beliefs regarding teaching C&E in the elementary classroom. They stated that it gives students important technical and social skills needed for their generation, that it was particularly important to integrate into the curriculum. Catherine added that STEM “is a building block that is every bit as important as the ABCs.” Wendy expressed a similar sentiment when saying, "I think that [engineering is] huge. I think having kids being exposed to it really young and showing them that these are the careers that you can choose from will get them excited about it.”

Curiously, the statements of belief were not congruent with expressions of efficacy (Figure 2), which reveals that a teacher can place great value on the teaching of STEM in the elementary classroom without feeling confident to teach it to their students. The very same teacher who stated that STEM “is a building block that is every bit as important as the ABCs” demonstrated the lowest self-efficacy. Fortunately, we saw a trend toward increased efficacy through taking action, either by low-risk implementation or by seeking out more training. Linda stated, “I’m taking the STEM endorsement because of the [professional development training].” The STEM endorsement is a two-year university program for practicing teachers to become trained how to integrate STEM activities into their regular curricula.

Teachers demonstrated that they held high beliefs towards C&E even without the important mediating factors of background, weekly trainings, and implementation. The teacher with the highest beliefs towards STEM did not even begin to implement C&E lessons in her classroom, and had no previous background in STEM or STEM instruction. Thus, while it is important that teachers begin by believing in the importance of STEM, belief itself appears insufficient to lead to increased self-efficacy. For that, implementation needed to occur.

4.4 Self-Efficacy

Teachers expressed varying degrees of self-efficacy for teaching C&E in the interview process. We coded self-efficacy as any expression of confidence or lack thereof in one's ability to teach C&E to elementary students. A low to high spectrum emerged from relationally rating the teachers’ expressions of efficacy. In the following section, we provide evidence for different ratings along our identified self-efficacy spectrum, starting with those who expressed the least self-efficacy for C&E.

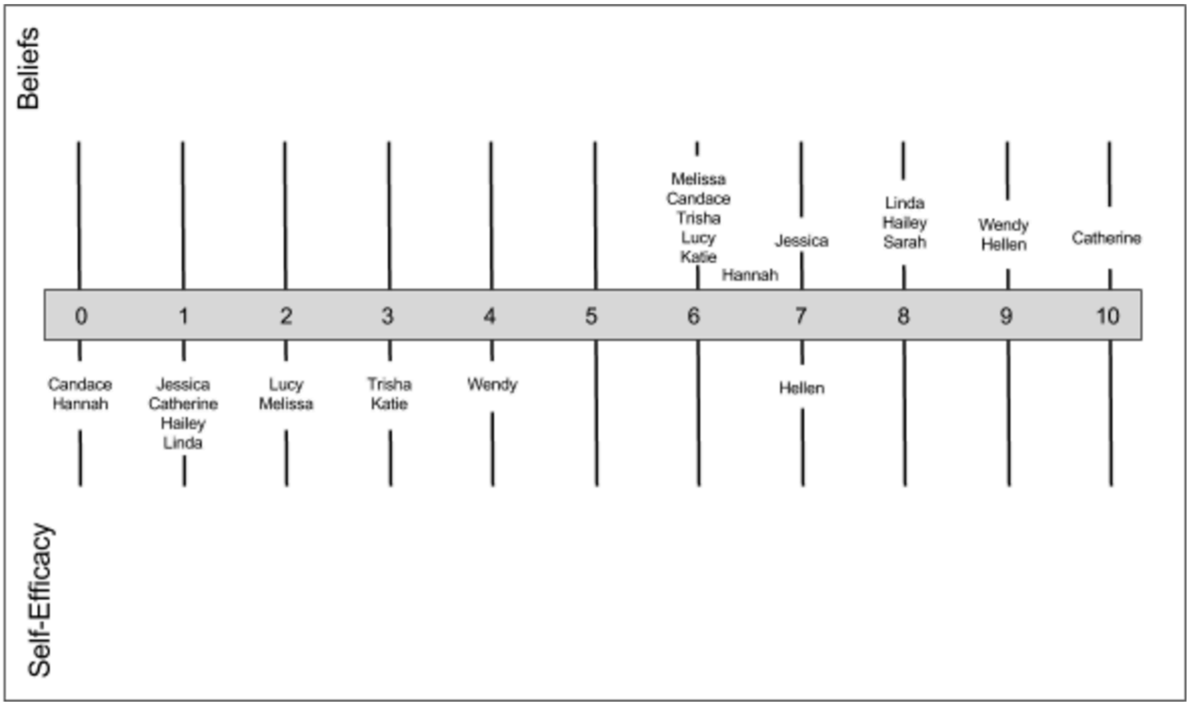

Figure 1. Teachers’ reported beliefs about (upper-half) and self-efficacy (lower-half) for computing and engineering, as revealed through semi-structured interviews.

Teachers who expressed no self-efficacy and had no background in STEM chose not to implement engineering or coding activities in their classrooms. We rated this as a 0 on our self-efficacy scale based on statements such as one from Sarah in Special Education, “it [i.e., my confidence] hasn’t changed a lot maybe just knowing a little bit more about what STEM is.” Teachers with low self-efficacy expressed apprehension to take C&E into their classroom, stating that they “would need to research more, and do the activities [themselves] a few times, and feel comfortable with it before [they] really felt like [they] could teach it.” Despite training, teachers at this level often felt like they did not “have the tools yet and don’t have the understanding.” Their lack of background in these and related fields heavily influenced their lower self-efficacy for teaching computing and engineering.

The majority of the teachers expressed a low, but present, self-efficacy. Their statements of efficacy ranged from “dangling on the side of the edge of the cliff,” to “hav[ing] a comfort level with C&E to approach it.” Teachers attributed minor changes in self-efficacy to the participatory trainings. For example, Catherine indicated that “slowly over time...I see maybe I could do this,” and that with increased training she was beginning to feel as though she would be able to implement C&E activities in the classroom. Likewise, Wendy stated that because of the trainings, she felt as though she could more quickly pick up the engineering and “incorporate it into my science time.” Participants of the training who fell into this category also often implemented either engineering or computing on a low level. For example, some teachers took C&E activities home to a child or other elementary-aged family member, or tried a brief extension activity with their students. Every teacher who participated actively in the training and began with low levels of implementation showed some level of increased self-efficacy for C&E. Teachers themselves expressed in interviews that these trainings and experience were contributing factors to their increases in efficacy.

Teachers with medium to higher self-efficacy were those who participated actively in trainings and often had background in STEM. These teachers not only participated in the training, but implemented their acquired knowledge to varying degrees. They participated in both low and higher risk implementation, such as full-classroom lessons and integration with core content delivery. Hellen shared that she “felt comfortable enough to introduce [Scratch] to the kids, and show them some of the features.” They shared that although some of these activities seemed unattainable for their teaching, that through training, implementation, and application of previous experiences, they were able to build a self-efficacy for teaching C&E in the classroom. Backgrounds of these teachers often already included previous STEM teaching experience or training in STEM areas. Curiously, even though these teachers expressed relatively higher self-efficacy, they attributed some of that to the trainings, through statements such as, “I think you helped me feel more comfortable with it and then I could help them [the students] feel like... it was an attainable thing it was useful for them to be able to code something that could be useful in the classroom.” Note, however, that it was likely a combination of the trainings, teachers’ own background with STEM and willingness to experiment with new material in the classroom that influenced reported increases in self-efficacy.

The importance of implementation on self-efficacy was further evidenced by teachers who began with lower self-efficacy. These teachers implemented a C&E lesson in their classroom regardless of their low self-efficacy for C&E. They also expressed a distinct willingness to experiment in the classroom without necessarily feeling like they had the confidence to teach C&E lessons in their classroom. The willingness to experiment was not quantifiable but an expressed comfort of attempting to teach new lessons in the classroom that they haven’t had experience with in the past. Willingness to experiment led to implementation which in turn led to improved self-efficacy. Note that *any* level of implementation (e.g., Linda taking computing lessons home to her son) tended to result in increased self-efficacy.

5. Discussion

The findings from this study reflect prior findings with teachers’ self-efficacy and beliefs in other content areas, while emphasizing how important it is to help teachers begin to implement computing and engineering (C&E) practices in their classroom. As they do so, they appear more likely to increase both beliefs about the importance of C&E as well as their own self-efficacy for teaching it. In the following discussion, we highlight how these results reflect prior findings and how such research can help us to better understand how to strengthen teachers’ beliefs about and self-efficacy for C&E in elementary education.

5.1 Teacher Beliefs About C&E

Teachers beliefs about a subject can be very influential as a teachers' stated beliefs about a subject often affects the way their students view that subject (Fang, 1996). Ertmer (2005) reported that teacher beliefs have been studied in nearly every subject except technology integration, which she since studied. To date, however, there are relatively few studies that have examined elementary school teachers' beliefs about either computing or engineering. This study aims to being to build a foundation on which we can better understand how elementary school teachers' beliefs play out and influence their teaching in two subject areas that are relatively new in elementary education: computing and engineering.

In general, teacher beliefs has proved to be a sticky subject, with a long and contradictory history. Over 20 years ago, Fang (1996) conducted a review of research on teachers' beliefs and found that, while for some teachers' beliefs provided a filter through which to interpret their practices (Nisbett & Ross, 1980), others found that their stated beliefs contradicted their practice. This was evident in a study by Bryan and Recesso (2006) wherein teacher candidates analyzed video evidence of their practice. Teachers were directed to first make a statement about how they believe science should be taught. They were then supposed to find confirming or contradictory evidence in their video-taped practice and share these findings in weekly meetings with their peers. One particular student had a stated belief-system about science education that appeared to clearly contradict his practice to all his peers. Yet, through several weeks of video analysis meetings, this student remained convinced that the two were in harmony. This demonstrated how difficult a teachers' beliefs about a subject could be to change.

Bridging Engineering, Science, and Technology (BEST) for Elementary Educators (Fitzgerald & Cunningham, 2013) found, on the other hand, that teachers' beliefs about engineering could be changed rather quickly. Over the course of a simple week-long training, they found that teachers' attitudes toward and beliefs about teaching engineering changed significantly. The results of our own study seem to reflect a similar trend. The fact that teachers' beliefs about the importance of computing and engineering were significantly different for our study school when compared to a similar school suggest that, through weekly trainings, teachers had changed their beliefs. This was especially apparent considering that the teachers' beliefs about science and engineering were not significantly different. Furthermore, as we interviewed teachers, we found that all teachers tended toward making stronger belief statements about C&E, with one even stating C&E is "as important as the ABCs" for students to learn.

In this study, it appeared that teachers' beliefs were affected by their own background, experience with regular trainings, and implementation. Importantly, these experiences reflect what Ertmer (2005) found as sources that affect teachers' belief changes in technology integration. She noted that teachers' beliefs are most likely to change through: (a) personal experiences, (b) vicarious experiences, and (c) socio-cultural experiences. In the case of our own teachers, we found during the trainings that the most powerful statements about the importance of C&E came from the teachers themselves and not the trainers who were promoting the practices. For example, one teacher spontaneously shared how her son, who had always struggled with mathematics, had begun to code the prior year. In learning to code, he began to spend long hours on single problems. She stated that she saw that transfer to his approach to mathematics and that he had greatly changed. In another instance, a different teacher indicated that students who had struggled in her fourth grade class also began to persevere through problems because of their engineering experiences. These experiences represent all three of Ertmer's observations on how teachers' beliefs about a subject might change. They provide a vicarious experience through which colleagues might imagine themselves teaching C&E and what outcomes they might expect. As more teachers have and share these experiences, they create a socio-cultural atmosphere that promotes a positive attitude toward C&E. Finally, past experiences with one subject (e.g., engineering) may lead a teacher to be more willing to believe that a related subject (e.g., computing) is important, as was the case with Hellen.

In light of this, we might recommend that trainings aimed at improving elementary educators' ability to teach C&E not only be focused on ensuring teachers have positive personal experiences implementing these in their classrooms, but that there be opportunity for teachers to share their experiences so that a positive culture can be built up. The caveat to this is that a series of negative experiences with C&E could have an equally powerful effect on the group's beliefs about C&E. Teachers sharing poor personal experiences could lead others to worry that they, too, would experience failure and have the opposite effect. Thus, it is important to monitor the socio-cultural atmosphere and experiences of teachers when they implement C&E and to highlight the positive.

5.2 Teacher Self-efficacy for C&E

While the teachers in our study all seemed to report higher levels of beliefs about the importance of teaching C&E, their individual self-efficacy for teaching these subjects varied greatly (even though, as a group, their self-efficacy was significantly higher than the comparison school). The most striking example occurred with Catherine, who had the highest belief in the importance of C&E, declaring it "as important as the ABCs," but who reported low confidence in her ability to teach it. The fact that teachers were not required to actually implement C&E in this first year proved to be a bit of unexpected provenance; had implementation been required, we may have missed the important effect venturing to try out these practices had on an individual teacher's self-efficacy. Likewise, we would likely have not noted the differing levels of teachers' implementation (because in year two, they will all be required to implement a full unit). Implementation varied in terms of the risk level associated with classroom teaching, with the lowest risk being taking it home and trying it with family, to the highest being including C&E in core curricula.

This implementation effect is supported by research on self-efficacy. The four sources for self-efficacy are: (a) mastery experiences, (b) vicarious experiences, (c) social persuasion, and (d) physiological responses (Bandura, 1997). Bandura found that mastery experiences are the most potent of these four sources, defining mastery experiences as experiences perceived by the individual to have been successful. This perception of success is important, as success begets success. In our study, teachers who perceived their implementation of C&E to be successful were more likely to implement it again, and in greater measures, in the future. For example, Trisha and Hellen both had prior success with engineering in their classrooms and reported they were more willing to implement computing activities as a result. Hellen's students actually surpassed her expectations of what they would produce, increasing the likelihood that she would again implement C&E in the future. Likewise, Linda's credited the training and her successful home experience as the motivation for enrolling in a two-year STEM endorsement program at a local university, even though her implementation was minimal, her success was significant enough to encourage further exploration and development.

The message in this is clear, even if somewhat simplistic: teachers need successful experiences implementing C&E. There is, however, an important nuance that emerged with our teachers—implementation can be variable. Because *mastery* means perceived success, even the lowest-risk implementation served as a mastery experience in this study. This suggests that, when attempting to help teachers have successful implementation experiences, they need not start with entire C&E lessons or units, but rather with shorter, lower-risk implementation; from there, teachers can work their way up the scale of increasing risk. Further research is needed to determine whether or not demanding that teachers start with higher-risk implementation leads to the same increases in self-efficacy. In fact, expecting too much of teachers too soon may be what Velthuis, Fisser, and Pieters found as the "implementation dip" in teachers' self-efficacy (2014, p. 258). That is, following professional development, teachers tend to demonstrate higher levels of self-efficacy for a subject; this enthusiasm tends to dip the following year when teachers are actually asked to put their new knowledge to the test (Moseley, Reinke, & Bookout, 2002; Ross, & Bruce, 2007). It is possible that expecting our teachers who did not implement this year to start by implementing a full, high-risk lesson next year will lead to such a dip.

We also recognize that the teachers who reported low self-efficacy in this study may have been reporting efficacy more akin to outcome efficacy. While teaching efficacy is the belief in one's ability to teach a specific content, outcome efficacy "is the belief that the behavior will lead to desirable outcomes" (Velthuis et al., 2014, pp. 446-447). In other words, while a teacher might begin to believe that they could teach a topic, they may not believe that doing so will make a difference. Swackhamer, Koellner, Basile, and Kimbrough (2009) found that teachers who had four or more courses in a content area had higher outcome efficacy than those who did not have a robust training. This is similar to AUTHOR's (2012) finding that it took a teacher multiple back-to-back-to-back trainings over a few years in order to start fully implementing new methods and content. In order to make this distinction, future research will need to tease out whether or not teachers believe they can teach a subject with their outcome expectancy for doing so.

6. Conclusion

In this study, all teachers at a Title I elementary school participated in year-long 45-minute weekly professional development trainings to learn computing and engineering (C&E) fundamentals. This was part of a four-year training plan to transition to more STEM-centered practices. We measured teachers' self-efficacy for and beliefs about C&E through a survey based on the *Teacher Efficacy and Attitudes Toward STEM Survey* (2012) and compared their self-efficacy for and beliefs about all STEM subjects to teachers at a sister Title I school with similar demographics. Teachers at both schools demonstrated similar self-efficacy and beliefs for science and mathematics, but significantly different results for technology and engineering. This suggested that the year-long training affected teachers' belief in the importance of C&E and their confidence to teach it themselves. Through further semi-structured interviews, teachers confirmed that training had a positive effect on their self-efficacy for and beliefs about C&E. While all teachers demonstrated fairly high beliefs about the importance of C&E for today's students, their self-efficacy varied greatly. We found that teachers' own prior background with STEM topics appeared to correlate with a higher self-efficacy.

Most importantly, while teachers were not expected to implement these practices during the first year trainings, we found that many teachers did venture to try teaching C&E, but did so to varying degrees of risk (i.e., the extent to which the implementation would affect normal classroom teaching). Teachers varied in their implementations, from taking the lessons home to try out with family, to teaching extension lessons, to an entire 8-week unit that resulted in student finals projects. Regardless of the level of implementation, the important element for increasing self-efficacy appeared to be whether or not teachers perceived the experience to be successful. One positive take-away from this finding is that, of all the mediating factors observed, implementation is among the most controllable and changeable (as opposed to background or willingness to experiment). Future research will need to examine the effect the level of risk has teachers' implementation. We need to better understand if expecting teachers to jump to high-risk implementation immediately has a negative effect on their self-efficacy.

We are in an era where there is increasing expectation that elementary school teachers will include computing and engineering in their repertoire of subjects. To date, there have been relatively few studies that examine how to prepare teachers to be confident in their ability to teach these new subjects. This study demonstrates that regular professional development can positively affect teachers' beliefs about C&E, but also highlights the importance of implementation on their self-efficacy. Teachers recognize the importance for C&E to a 21st century education, but they remain cautious in their confidence regarding whether or not they are able to teach these subjects.

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The Future of the Computing Curriculum: How the Computing Curriculum Instills Values and Subjectivity in Young People

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Abstract

In these early stages of implementation of the English computing curriculum policy reforms, there are uncertainties with regards to the intentions of computing to young people. To date, research regarding the English computing curriculum has been mostly concerned with the content of the curriculum, its delivery and surrounding pedagogy. In contrast this paper seeks to explore the underlying motivation and values embedded in the computing curriculum. We propose that this curriculum has been driven by the needs of industry and the economy. We use Schwartz's values to examine how the teaching of computing has been primarily embedded within the value of self-enhancement. We conclude, that by looking at this context and the underlying value structure, we can reflect on the dramatic effects of the narrative and discourse around the content, delivery and purpose of teaching computing to young people. We propose the narratives of curriculum, influence pedagogy and this in turn, has a powerful impact on the young people's view of themselves and the world we want to equip them to create.

Keywords: computing curriculum, education research, subjectivity, computer science education, Schwartz's values.

1. Introduction

Since the early 1980s there has been a long, well documented, history of teaching computing and ICT in schools, and there has been a variety of justifications for this practice (Passey, 2015). This has ranged from early attempts to teach various levels of coding and algorithms using tools such as logo the turtle, to teaching general ICT skills such as word-processing and spread sheets. Most recently in 2014 the new National Curriculum Framework for England has introduced the new area of 'Computing' with the stated purpose of "A high-quality computing education equips pupils to use computational thinking and creativity to understand and change the world" (DfE, 2014, 217).

In this paper we pose the question: What is the underlying context and driver of teaching computing in schools and what are the values that these drivers imply? The values and context of the computing curriculum have the potential to make a profound difference to how pupils approach the subject of computing.

We start this paper by looking at three key influences on the context of the computing curriculum these are; the policy context, the academic discourse surrounding new forms of work and the digital economy. We then use Schwartz's basic human values to look at the value structures of the computing curriculum and how different values place the computing curriculum in one of two distinct narratives of education. We conclude by looking at how these narratives impact on pupils as they learning about computing.

Although much of current research surrounding the computing curriculum is related to delivery and content, there is a clear need for further research that examines the fundamental values, motivations and impacts of teaching computing to young people.

2. Literature and Policy Context

There are two fields which can be seen as attempting to describe the what the world of work will look like for pupils