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An Investigation of Elementary Teachers' Self-Efficacy for and Beliefs About the Importance of Engineering Education

Khristen Lee Massic

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

Steven L. Shumway, Chair
Kip Christensen
Michael P. Miles

School of Technology

Brigham Young University

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ABSTRACT

An Investigation of Elementary Teachers' Self-Efficacy for and Beliefs About the Importance of Engineering Education

Khristen Lee Massic
School of Technology, BYU
Master of Science

In order for the United States to regain its global standing in science and engineering, educational and governmental organizations have started to re-emphasize science, technology, engineering, and math content in k-12 classrooms.

While some preliminary research has been conducted on student and teacher perceptions related to engineering, there has been little research conducted related to teachers' beliefs about the importance of engineering content in their classrooms and relatively few studies have investigated elementary teachers teaching engineering self-efficacy. Current studies have investigated the impact of professional development on teachers teaching engineering self-efficacy but these studies were conducted with limited sample sizes, for relatively short professional development timeframes, with a restricted sample and these studies did not include the implementation component of professional development. Research is needed to not only determine elementary teachers' beliefs about the importance of engineering content in their classrooms, but to also investigate if these teachers' levels of confidence (teaching engineering self-efficacy) can be increased by exposure to STEM-related professional development and the implementation of engineering activities in their classrooms.

The research question in this study was to determine if scored responses from a pre-survey taken by teachers participating in an engineering-related professional development would differ from scored responses on two subsequent post-surveys following the professional development and following implementation on the teachers' beliefs about the importance of teaching engineering content at the elementary level and the teachers' confidence in the ability to teach engineering concepts at the elementary school level.

While the teachers in this study generally had positive beliefs about the importance of teaching engineering at the elementary level, an investigation of the individual nine beliefs items from the survey indicated that they are less likely to consider engineering part of the basics and that it should be taught more frequently.

One of the major conclusions from this study was that teachers' teaching engineering self-efficacy can be significantly strengthened through participation in a week-long professional development series. Furthermore, while not statistically significant, the implementation of these activities into their classroom can also help improve teachers' confidence in their ability to teach engineering-related activities.

Keywords: elementary STEM education, STEM, engineering education, beliefs, self-efficacy

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1 INTRODUCTION

1.1 Introduction

The launch of the Russian Satellite Sputnik in 1957 impacted the United States in that it created a fear that the U.S. was falling behind the Soviets in technological capability. This resulted in legislation and changes in the education system of the United States that inspired a generation of innovation, technology and engineering professionals in America. After Sputnik, the United States continued to be a leader in science, technology, and engineering, resulting in the nation leading globally in the number of students graduating with engineering degrees only a decade after Apollo (Woodruff, 2013). Unfortunately, over the past 20-30 years, when compared to other developed countries, the achievement of U.S. students appears to be inconsistent with the nation's role as a world leader in scientific and engineering innovation and there is a growing concern that the United States is no longer preparing a sufficient number of students, teachers, and professionals in the areas of Science, Technology, Engineering, and Mathematics (STEM) (Kuenzi, 2008).

For example, among the 34 Organization for Economic Co-operation and Development (OECD) countries participating in the 2012 Program for International Student Assessment (PISA), the U.S. ranked 27th in mathematics literacy and 17th in science literacy (Kelly, 2013). Although degrees in some STEM fields have increased in recent decades, the overall proportion of STEM degrees awarded in the United States has historically remained at about 17% of all postsecondary degrees awarded. According to the National Science Foundation (NSF), the United States currently ranks 20th among all nations in the proportion of 24-year-olds who earn degrees in natural science or engineering (Kuenzi, 2008).

In addition to declining test scores, data collected from students taking the American College Testing (ACT) exam also indicates that fewer U.S. students are expressing interest in STEM-related majors and those who are interested are not prepared academically for STEM-related majors. From 1996 to 2006, the percentage of ACT-tested students who said they were interested in majoring in engineering dropped from 7.6 percent to 4.9 percent, while those interested in majoring in computer and information science dropped from 4.5 percent to 2.9 percent (ACT, 2006). A recent report from ACT shows that of the 1.9 million graduates who took the ACT in 2015, 49 percent had an interest in STEM-related majors. However, based on the new ACT STEM College Readiness Benchmark, too many of these students are not prepared to succeed in the rigorous math and sciences courses that are required of STEM majors (ACT, 2015).

1.2 Renewed Emphasis on STEM Education

In order for the United States to regain its global standing in science and engineering, educational and governmental organizations have started to re-emphasize science, technology, engineering, and math content in k-12 classrooms. For example, in the 1990's the National Science Foundation created the acronym "STEM" for Science, Technology, Engineering, and Math in order to show the common relationship between these subjects (Woodruff, 2013). Additionally, many government led studies and legislation have tried to address this push for STEM education. For example, in a Congressional Research Service report written by Kuenzi

(2008), two studies were investigated in regards to the federal role in promoting STEM education. Kuenzi found that in FY2004, 207 STEM education programs were appropriated nearly $3 billion and in FY2006, 105 STEM education programs also received just over $3 billion in funding.

In 2009, President Obama introduced his “Educate to Innovate” campaign, which has resulted in over $1 billion in financial and in-kind support for STEM programs. As a result of legislation, there is a strong emphasis on K-12 STEM education, afterschool STEM programs, and STEM fairs.

Additionally, professional organizations that support educators within the “T&E” of STEM have made recent changes. For example, in 2000, the International Technology and Engineering Educators Association compiled valuable “Standards for Technological Literacy” to enable educators to better address the “T&E” in their classrooms. These guidelines served to structure K-12 classrooms in order to produce students ready for careers in science, technology, engineering, and math (Woodruff, 2013). Other examples of a renewed STEM emphasis include the International Technology and Education Association (ITEA) changing its name to International Technology and Engineering Educators Association (ITEEA), the American Society for Engineering Education (ASEE) adding a K-12 division, and the inclusion of engineering in the newly adopted national Science Standards (NGSS Lead States, 2013).

1.3 Engineering at the Elementary Level

Research conducted prior to President Obama’s “Educate to Innovate” campaign showed that the previously mentioned studies by the Government Accountability Office (GAO) and American Competitiveness Council (ACC) found that the majority of effort for federal STEM education programs supported "graduate and post-doctoral study in the form of fellowships to improve the nation's research capacity" (Kuenzi, 2008). Since the publication of those studies, a study by Maltese and Tai (2010) suggested that the majority of scientists and graduate students in science developed an interest in science at the elementary level. Likewise, a study by Cvencek, Meltzoff, and Greenwald (2011) reports that children as early as second grade, decide whether or not they are successful at mathematics. This leads to a perceived need for education and education researchers to focus research and curricular development and support on STEM education at the elementary level.

While the focus on STEM curriculum development has been primarily at the secondary education level, engineering curricula for the elementary level is gaining popularity. One of the causes of this popularity could be that the recent Next Generation Science Standards (NGSS) includes standards relating to engineering design at the elementary level (NGSS Lead States, 2013). Additional evidence of the rising popularity of engineering content in elementary schools can be found in the following three elementary engineering curricula: 1) Engineering is Elementary (EiE) (www.EiE.org) 2) ITEEA's Engineering by Design (EbD) (http://www.iteea.org/STEMCenter/EbD.aspx), and 3) Project Lead the Way (PLTW) Launch (https://www.pltw.org/our-programs/pltw-launch).

1.4 Current Research in Teaching Engineering at the Elementary Level

Much of the research conducted thus far in relation to teaching engineering content at the elementary school level has focused on:

1. Students' basic concepts of and attitudes toward engineering and technology (Knight, 2004; Cunningham, 2005; Lachapelle, 2007; Lachapelle, 2012; Lachapelle, 2013),

2. The impact of specific engineering curricula on students' perceptions of and interest toward engineering-related professions (Lachapelle, 2007; Lachapelle, 2008; Lachapelle, 2011; Lachapelle, 2013; Rynearson, 2014; Macalalag, 2010),
3. Teacher perceptions of the impact of elementary engineering curricula on students' understandings of science and engineering (Carson, 2007; Faux, 2006; Faux, 2007; Faux, 2008; Lachapelle, 2011),
4. The impact of professional development on teachers' pedagogy and whether they are more apt to use an engineering design process in other content areas when teaching (Faux, 2006; Faux, 2007; Faux 2008; Carson, 2007; Cunningham, 2010), and
5. The impact of professional development on the ability to impact teacher's confidence in their ability to teach elementary-level engineering content (teaching engineering self-efficacy) (Nadelson, 2013; Wendt, 2015; Rich, 2017-in press).

The study of efficacy is important because "among the potential obstacles to successful integration of engineering in STEM, particularly in elementary curricula, are female teacher candidates' self-beliefs about what constitutes engineering and engineers and about their own ability to teach engineering concepts" (Wendt, 2015). Nadelson, et al. (2013), further remark that many elementary teachers have a constrained background knowledge, confidence and efficacy for teaching the "E" component of STEM and this may hamper student learning. The fact that teachers are not confident in their abilities to teach engineering is not surprising given that fact that the majority of elementary teachers receive no engineering-related instruction in their preservice teacher experience and that within preservice programs teacher candidates typically only complete two college-level science courses and two college-level mathematics courses (Fulp, 2000; NRC, 2012). To overcome the limitations associated with minimal preparation in

STEM, many including the National Research Council (NRC), (2007) and National Science Teachers Association (NSTA) (2002) are recommending that teachers engage in continuing education. This continuing education is typically in the form of in-service or professional development which according to a report by Ross and Bruce (2007) has a good potential to impact teachers' self-efficacy. Self-efficacy refers to an individual's confidence to competently demonstrate capacity within a specific subject area or task. These teachers' beliefs about the importance of engineering content for their students as well as their perceived ability or self-efficacy about their abilities to teach this content is thus an important construct that needs to be explored.

1.4.1 Teaching Engineering Self-Efficacy Research

Nadelson et al., (2013) conducted a research study in which they reported significant and consistent increases in pre-post assessments of teacher confidence, efficacy, and perceptions of STEM after a 3-day summer institute. This study was repeated two successive years, with 36 teachers during year one, and 32 teachers during year two, with like results each year.

Wendt et al. (2015), conducted a study which focused on pre-service female teacher candidates (n=5), and reported findings in which participants' self-efficacy for teaching elementary engineering concepts increased after taking part in a pre-service course that involved university supervisor modeling, collaborating in teacher candidate teams to plan a unit, and implementation of the prepared unit under supervision of the university supervisor and mentors.

While both these studies provided valuable data on the potential of preservice and professional development to positively impact teachers' confidence and self-efficacy in teaching elementary level engineering concepts, there were some study limitations that need to be considered when generalizing the findings from these studies to other educational environments. For example, in the report of their findings, Nadelson et al., (2013), suggest that future studies include a broader range of participants as the subjects in their study were chosen from a group of teachers that had indicated a previous self-interest in STEM. It would be interesting to compare the findings of their study with a sample of teachers with no previous disposition to STEM subjects and to do so with a larger sample size of teachers. Additionally, while the Nadelson et. al (2013) and Wendt et al. (2015) studies both looked at the impacts of professional development activities on teachers teaching engineering self-efficacy, it would be informative to expand the study to not only look at the impact of professional development but also to investigate the impact of the implementation of the engineering design activities throughout a school year.

1.5 Problem

Katehi, Pearson, and Feder (2009), and Roehrig et al. (2012) have called for research that looks at successful ways of integrating engineering and the other STEM disciplines in K-12 classrooms. While some preliminary research has been conducted on student and teacher perceptions related to engineering, there has been little research conducted related to teachers' beliefs about the importance of engineering content in their classrooms and relatively few studies have investigated elementary teachers teaching engineering self-efficacy. Current studies have investigated the impact of professional development on teachers teaching engineering self-efficacy but these studies were conducted with limited sample sizes, for relatively short professional development timeframes, with a restricted sample and these studies did not include the implementation component of professional development. Research is needed to not only determine elementary teachers' beliefs about the importance of engineering content in their classrooms, but to also investigate if these teachers' levels of confidence (teaching engineering self-efficacy) can be increased by exposure to STEM-related professional development and the implementation of engineering activities in their classrooms.

1.6 Purpose

The purpose of this study is to investigate the impact of professional development and curriculum implementation on: 1) elementary school teachers' beliefs about the importance of engineering curriculum at the elementary level and 2) teachers' confidence in their ability to teach engineering concepts (teaching engineering self-efficacy).

1.7 Research Question

How do teachers' perceptions of their own teaching engineering self-efficacy and their beliefs about the importance of elementary-level engineering teaching change in response to professional development in STEM education and the long-term implementation of engineering-related activities into their classroom as measured by the Beliefs and Self-Efficacy in Elementary Engineering-Teachers Scale (BSEEE-T)? Specifically, will scored responses from a pre-professional development survey taken by teachers participating in an engineering-related professional development differ from post-professional development and implementation survey scores from these same teachers on the following:

1. Beliefs about the importance of teaching engineering content at the elementary level.
2. Confidence in their ability to teach engineering concepts at an elementary school level (Teaching Engineering Self-efficacy).

Furthermore, will the magnitude of any difference between the mean score of the pre and post survey be large enough to be considered statistically significant?

To answer this research question, the Beliefs and Self-Efficacy in Elementary Engineering-Teachers Scale (BSEEE-T), an instrument that has been validated for this purpose, will be used to collect pretest/posttest data at two separate intervals 1) Before and after a STEM professional development series coordinated at a district level, 2) Before and after a year-long STEM implementation period. Data will be analyzed to see if differences in pretest and posttest scores are statistically significant.

2 REVIEW OF LITERATURE

2.1 Introduction to Review of Literature

Current research regarding engineering instruction and activities at the elementary school level include those focused on 1) student and teacher conceptions of technology and engineering, 2) impact of specific engineering curricula on students—both understanding of concepts and attitudes toward careers, 3) teachers' perception of specific engineering curricula, 4) impacts of specific engineering curricula sponsored professional development and teacher implementation, and 5) teaching engineering self-efficacy of elementary teachers.

In this review of literature, data presented in previous studies have been summarized in an attempt to introduce the reader to previous research that has been done on the topic of teaching engineering and self-efficacy of elementary teachers.

2.2 Need for Review of Literature

Most of the reviews of literature conducted on the topic of teaching engineering have focused primarily on secondary education or post-secondary education. In addition, the majority of the conducted research regarding STEM education has focused primarily on science and mathematics. A review of literature was needed in order to discover recent primary research regarding teaching engineering at the elementary level.

2.3 Review Objectives

The specific objective of the review of literature was to summarize primary research studies which specifically looked at teaching engineering at the elementary level.

2.4 Review Procedures

2.4.1 Selecting Studies

The Technology and Engineering Education Research Guide provided by Brigham Young University was employed for primary and secondary research studies for this review of literature. Combinations of the following keywords were used from The Thesaurus of ERIC Descriptors: Teaching AND Engineering AND Elementary AND Self-Efficacy, to search the following databases: ERIC, Academic Search Premier, Computers and Applied Science Complete, and ProQuest. Requiring the keywords to be in the title or descriptors of the reference, using only studies from 2000 to 2016, and only peer-reviewed articles limited the number of relevant sources to 176. Abstracts from each of these sources were analyzed. In addition, all abstracts of studies that were conducted for Engineering is Elementary were also analyzed. Articles which met the following inclusion/exclusion criteria were reviewed:

1. The research must have been conducted in an educational setting,
2. The research must have been specifically looking at teaching engineering curriculum or concepts at the elementary level,
3. The research must have collected data in regard to teachers' self-efficacy of teaching engineering.

2.5 Review of Previous Research

There is a growing concern that the United States is no longer preparing a sufficient number of students, teachers, and professionals in the areas of Science, Technology, Engineering, and Mathematics (STEM) (Kuenzi, 2008). Students in the United States are ranking lower than other developed countries in mathematics and science on standardized tests like PISA. In addition to declining test scores, fewer U.S. students are expressing interest in STEM-related majors.

2.5.1 Current STEM Curricula

Engineering is Elementary (EiE) is a National Science Foundation (NSF) instructional materials funded project that was started in 2003 at the National Center for Technological Literacy in the Boston Museum of Science. EiE serves students and educators in grades K-8 by providing research-based curriculum materials in addition to providing professional development workshops. Currently, EiE features 20 curricular units that can be integrated into existing science units.

ITEEA is the leading professional organization for technology and engineering educators and has been an "advocate for strong teaching and learning methods used to advance curriculum and instruction keeping pace with our rapidly advancing, highly sophisticated technological society" (ITEEA, 2016). Because of this, ITEEA has created a K-12 curriculum called Engineering by Design (EbD). The engineering curriculum that is provided for grades K-6 is Engineering by Design-Technology, Engineering, Environment, Mathematics, and Science (EbD-TEEMS). EbD-TEEMS is an integrative, engineering curriculum with each grade having a unit that should take 1-6 weeks, but is flexible to meet the varying needs of elementary classrooms.

Finally, Project Lead the Way (PLTW) is a non-profit organization that provides engineering-related curriculum and teacher training across the United States. PLTW has pathways in computer science, engineering, and biomedical science for secondary education. In 2013, PLTW announced the development of a K-5 curriculum, “Launch”, to support existing pathways. The PLTW Launch curriculum includes 24 modules that span K-5. These modules are 10-hours each and they are presented in pairs to create a unit.

2.5.2 Student and Teacher Conceptions of Technology and Engineering

The first topic of research that has been conducted regarding elementary schools was student and teacher perceptions of technology and engineering. Knight and Cunningham (2004), Cunningham et al. (2005), Lachapelle and Cunningham (2007), Lachapelle et al. (2012), and Lachapelle et al. (2013) all conducted research in regards to student perceptions. In each of these studies, various instruments were used to assess students’ understanding of technology and engineering. These instruments included the Draw an Engineer Test, which asks for children to draw engineers at work then asking the child to describe his/her drawing with words (Knight, 2004). A pre- and post-test of the “What is Engineering?” instrument was given that included captioned images of people working and then asking what tasks an engineer would do as well as the open-ended question, “What is an engineer?” (Cunningham, 2005; Lachapelle, 2007). In the study conducted by Lachapelle et al in 2012, the “What is Engineering?” instrument was further refined to include questions regarding types of activities are important to the work of engineers (Lachapelle, 2012; Lachapelle, 2013).

Although the testing instruments varied as well as the population, the results of these studies suggest that students' initial responses focus heavily on structures, cars/machinery, and computers (Knight, 2004). Findings were similar in 2005 with the "What is Engineering?" instrument—students were least likely to identify engineering tasks from non-mechanical/civil engineering fields (Cunningham, 2005). Likewise, research conducted in 2012 finds that students are focusing more on the subject of the work rather than the type of work being done (Lachapelle, 2012). In the previously mentioned studies, when a post-test was given after engineering instruction, students' responses changed and had more varied responses. The "What is Engineering?" instrument was also administered to teachers and yielded similar responses to the students, although they were more likely to distinguish between engineering types of work and non-engineering work (Cunningham, 2007).

2.5.3 Impact of Specific Engineering Curricula on Students—Both Understanding of Concepts, and Attitudes Toward Careers

The second topic of research that has been conducted regarding elementary schools is the impact of specific engineering curricula on students—both understanding of and concepts and attitudes toward engineering careers. Studies conducted by Lachapelle (2007); Lachapelle et al. (2008); Lachapelle, Cunningham, Jocz, Kay et al. (2011); Lachapelle, Cunningham, Jocz, Phadnis, et al. (2011); Lachapelle, Jocz, and Phadnis (2011); Lachapelle, Hertel, Phadnis, et al. (2013); Lachapelle, Hertel, Shams, et al. (2013) compared pre- and post-assessments regarding general engineering and technology content knowledge as well as science concepts while using the EiE curricular units. Results of three rounds of assessments were studied at various intervals of the EiE curricula. Studies found that EiE students performed significantly better than the control. Because of convenience sampling rather than randomized sampling, these studies should be considered promising, but not conclusive.

Another study conducted by Rynearson, Douglas, and Diefes-Dux (2014) investigated which learning outcomes teachers' perceived their students experienced by integrating engineering lessons using the EiE curriculum into their classrooms. Teachers of grades 2-4 from participating elementary schools volunteered to implement engineering lessons for two years and also participate in summer professional development in order to learn engineering content knowledge and pedagogy. The research was collected after the first year of participation. In response to the question, "What do you think students learned?" Teachers perceived that students learned more interpersonal skills rather than technical content.

Likewise, Macalalag and Tirthali (2010) conducted a study based on the Partnership to Improve Student Achievement (PISA) professional development program that involved intensive teacher professional development and training over two years. Analysis of pre and post-test scores from Year 1 and Year 2 showed that students significantly improved content knowledge in engineering and science and the post-test scores of students in the treatment group were significantly higher than those in the control group.

In addition to content assessments, Lachapelle, Phadnis, Jocz, and Cunningham (2012); Cunningham and Lachapelle (2010); Lachapelle, Jocz, et al. (2011); and Lachapelle, Hertel, Phadnis, et al. (2013) collected pre- and post-surveys from students who completed the Engineering is Elementary curriculum. Students who completed EiE were more likely than control students to report interest in being an engineer on the post-survey. The EiE students were also significantly more likely to report interest in and comfort with engineering jobs and skills. In addition, changes from pre- and post-surveys showed students responding significantly more positively to statements about science and engineering, specifically as professions (Lachapelle, 2013).

2.5.4 Teachers' Perception of Specific Engineering Curricula

The third topic of research that has been conducted regarding elementary schools is teachers' perception of specific engineering curricula. Studies conducted by Carson and Campbell (2007a, 2007b); Faux (2006, 2007, 2008); Lachapelle, Cunningham, Jocz, Kay, et al. (2011); Lachapelle, Cunningham, Jocz, Phadnis, et al. (2011) asked teachers to rate EiE curricular materials after professional development and after implementing EiE with their students. Teachers felt that the EiE materials are well designed, fit into the required curricula, and well matched to the level of students (Faux, 2007). Teachers also felt that the EiE units positively affected their students' motivation (Lachapelle, 2011; Lachapelle, 2011). When teachers were asked to compare EiE and traditional elementary curricula, "teachers strongly agreed that with EiE, students learn science concepts better, are more engaged, are more collaborative, are more creative, and make real world science/engineering connections" (Faux, 2008).

2.5.5 Impacts of Specific Engineering Curricula Sponsored Professional Development and Teacher Development

The fourth topic of research that has been conducted regarding elementary schools is impacts of specific engineering curricula sponsored professional development and teacher implementation. EiE staff conducted workshop evaluations at each EiE professional development program that was offered. Faux (2006, 2007, 2008); Carson and Campbell (2007a); and Cunningham et al. (2010) compiled teacher responses to these workshop evaluations.

Teachers said they felt that the workshops prepared them to do an engineering project in their classroom (Faux, 2007). Teachers also reported that they become knowledgeable about how engineering is practiced (Faux, 2007). Teachers further reported changes in their teaching pedagogies after learning and teaching EiE in their classrooms. After participating in EiE, teachers were more apt to use an engineering design process in other content areas. Teachers reported significant changes in the use of problem-solving strategies and attitudes towards those strategies (Faux, 2008).

2.5.6 Self-Efficacy of Elementary School Teachers in Regard to Engineering

Bandura defined self-efficacy as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 3). A study by Nadelson et al. (2013) implemented a 3-day summer professional development program over two years with two independent cohorts to "address K-5 teacher confidence for, attitudes toward, knowledge of, and efficacy for teaching inquiry-based STEM." The research questions were based on the notion that teachers who lack knowledge could lead to feelings of uneasiness about his/her teaching abilities of a particular subject. Teachers from six elementary schools in one school district were asked to participate in the professional development training which involved whole-group presentations on best instructional practices in STEM. In order to measure efficacy for teaching STEM, Nadelson et al. used the Science Teaching Efficacy Belief Instrument (STEBI; Riggs, 1990) as the survey instrument, although some questions were rephrased to include "STEM" instead of "science." While this study looked at teaching self-efficacy of STEM, the research question that pertained to efficacy compared other factors like years of teaching experience and comfort with teaching STEM prior to the professional development. Another possible problem with this study is that the instrument was not specifically designed for STEM.

Efficacy was also compared between the first and second year of the program using the STEBI instrument (Nadelson, 2013). Nadelson et. al found significant and consistent increases in pre- to post-professional development assessments of teacher confidence, efficacy, and perceptions of STEM.

Because of the desire to increase the number of students who excel in mathematics and science, it is necessary to make a change in teacher preparations programs in order to prepare teachers to teach such content (Wendt, 2015). Wendt et al. (2015) studied five female elementary teacher candidates as they participated in Elementary Engineers Academy II (EEA II) as part of their coursework. EEA II included instruction and modeling of an engineering design challenge by the university supervisor while participants observed and participated as students. The study used the engineering design unit *Float Your Boat* which is a part of *Picture Perfect Science Lessons, K-5: Using Children's Books to Guide to Inquiry*, published by NSTA Press (Wendt, 2015). Teacher candidates were interviewed prior to after instruction, and asked about their initial understandings of engineering design concepts and STEM; and participants were asked to examine their own "preconceived ideas about STEM and engineering and to explore how their thinking developed through instruction, modeling, hands-on practice in their methods courses, and application in elementary classrooms" (Wendt, 2015). The post-implementation interviews revealed that the participants' self-efficacy for teaching elementary engineering concepts increased due to recognition that "teaching engineering concepts to elementary children required knowledge and skills she already possessed" (Wendt, 2015). Wendt et al. (2015) concluded that "teacher candidates need to believe in their own capabilities for teaching in the STEM disciplines, particularly for teaching engineering" in order to help the success of the teachers as well as their future students.

The Bridging Engineering, Science, and Technology (BEST) for Elementary Educators project's goal was to increase preservice teachers' perceptions of and confidence in teaching STEM in the elementary classroom in Massachusetts. "Massachusetts' curriculum frameworks state that 'approximately one-quarter of PreK-5 science time should be devoted to technology/engineering'" (Fitzgerald, 2013). The project grant funded faculty trainings with four Massachusetts community colleges and their 4-year transfer partners to "implement engaging engineering and technology content in preservice teacher preparation courses" (Fitzgerald, 2013). Faculty members then implemented concepts learned during the faculty trainings into the following year's courses. A pre- and post-survey was created for students who were enrolled in those courses where participants were given 31 statements about 1) the engineering design process, 2) context in how technology and engineering fit into society, and 3) technological products that are a result of engineering. Participants were asked to rate their agreement with these statements on a 1-10 Likert scale. An additional survey was administered to students who were preservice teachers and gathered information regarding participants' attitudes toward teaching engineering in the future. This procedure was implemented for three academic years. Researchers received enthusiastic responses from faculty participants about using engineering into and that engineering is likely to be 20% of the lessons taught. Results of student surveys showed strong student gains, although there was variation in students' gains between colleges. Results for the preservice teachers showed significant improvement.

2.6 Summary

While research in STEM education is increasing, there is still little research specific to engineering education at the elementary level. Current research regarding engineering instruction and activities at the elementary school level include those focused on 1) student and teacher conceptions of technology and engineering, 2) impact of specific engineering curricula on students—both understanding of concepts and attitudes toward careers, 3) teachers' perception of specific engineering curricula, 4) impacts of specific engineering curricula sponsored professional development and teacher implementation, and 5) teaching engineering self-efficacy of elementary teachers. While the findings of this research are suggesting that engineering education at the elementary level is necessary, studies and research is sparse regarding teacher self-efficacy of engineering and how professional development can influence teacher self-efficacy.

3 METHODOLOGY

3.1 Purpose

The purpose of this study was to investigate how teachers' perceptions of their own teaching engineering self-efficacy and their beliefs about the importance of elementary-level engineering teaching change in response to professional development in STEM education and the long-term implementation of engineering-related activities into their classroom as measured by the Beliefs and Self-Efficacy in Elementary Engineering-Teachers Scale (BSEEE-T). Specifically, will scored responses from a pre-professional development survey taken by teachers participating in an engineering-related professional development differ from post-professional development survey scores from these same teachers on the following:

1. Beliefs about the importance of teaching engineering content at the elementary level.
2. Confidence in their ability to teach engineering concepts at an elementary school level (Teaching Engineering Self-efficacy).

Furthermore, will the magnitude of any difference between the mean scores of the pre and post surveys be large enough to be considered statistically significant?

3.2 Procedures

3.2.1 Population and Sample

The target population for this study was elementary teachers grades K-6 within the Alpine School District located in Utah County, Utah. The sample population consisted of teachers from seven of the fifty-seven elementary schools within the district. The district includes 78,000 students, 87.3% of which identify as Caucasian, and 4.7% as English Language Learners. The seven schools in this study were chosen representative of the diversity of the population of the district having an SES that ranged from 25.0%-88.4% of student populations that qualified for free or reduced meals (FARMS), with an average of 46.1% of students qualifying for FARMS. All schools participating in the study feed into the same high school. Additionally, the schools that participated in this research study were chosen based upon the school administrations' selection to participate in Alpine School District's STEM professional development program in during the 2016-2017 school year.

3.2.2 Description of Professional Development

School administrators of each elementary school were notified in March that they would be participating in the STEM professional development provided by the district. The professional development was attended by all teachers in the school (K-6) and included special education teachers, specialty teachers (computer specialists, art, etc.), and grade-level teachers. The teachers from each of the schools were gathered at a common school for the purposes of the professional development and professional development sessions were divided based on grade level with Week #1 for fifth and sixth grade teachers, Week #2 for third and fourth grade teachers, and Week #3 for kindergarten through second grade teachers. The professional development sessions took place in June, beginning the week following the end of the school-year and lasted four days for each of the three weeks.

The schedule for Week #1 (fifth and sixth grade) was:

Day 1 – Teachers from both grades (approximately 50-60) gathered together in a large common area in the school gymnasium. The presenter was a university teacher-education professor with experience in STEM education assisted by a subject expert, grade specific teachers with previous STEM classroom experience. Principals of the schools were also present and participated in the Engineering Design Process activities and provided administrative support. The presenter introduced the concept of the engineering design process and the activities for the day enabled teachers to engage in this process through engineering-related design problems. Many of the activities were based upon the Engineering is Elementary (EiE) curriculum created by the Boston Museum of Science.

Day 2 – Teachers were divided into groups by grade (about 25-28 per grade). Engineering activities for the day were designed and matched to the grade-specific science outcomes as given by the Utah State Board of Education. Discussion and activities were led by the subject expert teachers for each grade with the university professor rotating between groups.

Day 3 – Similar format as Day 2, but with additional activities that corresponded to specific science objectives for each grade as given by the Utah State Board of Education.

Day 4 – During the morning, teachers were organized by grade and subdivided into small groups to design their own engineering design activities for other fifth and sixth grade classroom objectives that were not previously given as examples. In the afternoon, teachers participated in a “make and take” session where teachers gathered materials and supplies they would need to teach the activities covered on days one, two, and three—thus allowing them to be prepared for those lessons during the school year. Each of the next two weeks of professional development followed the same format, but with the other grade levels.

In addition to the professional development during these weeks, the professional development provider from the university periodically provided additional sessions with grade-specific teachers throughout the school year as teachers were engaged in implementing the activities into their classrooms. These were typically two-hour sessions on a Monday afternoon during the teachers' professional learning community (PLC) sessions with grade-specific teachers gathering at a common school. During the school year, at least one supplementary professional development session was provided to teachers at each grade level.

3.2.3 Design and Description of Instrument

For this study, elementary teachers from the seven schools participating in the Alpine District professional development session were given the Beliefs and Self-Efficacy in Elementary Engineering-Teachers (BSEEE-T) instrument through an online survey three times.

1. Survey #1: Pre-professional development. This round of the survey was given to the teachers in March 2016 before they had knowledge that they would be part of a STEM professional development offered by the school district. Approximately 140 teachers were given the survey with 105 (75%) completing the survey correctly with useful data.
2. Survey #2: Post-professional development and pre-implementation. This version of the survey was given to the teachers at the beginning of the school year after participation in the professional development but prior to the school year and implementation of the

engineering activities with their students. Seventy-nine (n=79) or 56.4% of the teachers completed this round of the survey.

3. The final distribution of the survey was given in May 2017 at the end of the school year after the teachers conducted an implementation of the engineering activities presented during the professional development. One-hundred twenty-one (n=121) or 86.4% of the teachers completed this round of the survey.

The BSEEE-T survey instrument was created and tested for validity and reliability by a team of professors and graduate students at Brigham Young University as well as researchers for Alpine School District during the 2015-2016 school year. In the BSEEE-T, participants were asked to rate "Beliefs" and "Efficacy" statements based on a Likert 6-point scale with 6= Strongly Agree, 5=Agree, 4=Somewhat Agree, 3=Somewhat Disagree, 2=Disagree, 1=Strongly Disagree. The BSEEE-T instrument consisted of nine items that measure beliefs and nine items that measure self-efficacy. Data from these nine items were combined for one mean score for beliefs and one mean score for self-efficacy.

As part of the instrument development process, Cronbach alpha reliability coefficients were calculated with values of α=.92 for the Belief and α=.85 for the Self-efficacy sections of the instrument. These results suggest that the items on the instrument reliably measured the underlying constructs of Belief and Self-efficacy.

3.2.4 Data and Implementation

The BSEEE-T instrument (Appendix A) was provided to the teachers online via Qualtrics survey software. The Alpine School District's Research office sent out a letter to the elementary school principals informing them of the survey. The principals announced the survey to the teachers. Implied consent was obtained via the first page of the survey, which explained the purpose of the research and that participation in the survey indicated the participant's consent to participate in the study.

In summary, participants in this research study completed the BSEEE-T three times: once as a pretest, once as a post-test following district initiated professional development, and then again after implementing the engineering curriculum during the school year. Participants remained identifiable so that we could link the scores and measure change in teacher beliefs and efficacy over time. To protect teachers' identities, we assigned each teacher an ID number. This number was used when inputting the data for analysis of each iteration of the BSEEE-T.

3.2.5 Analysis

Estimates of statistical significance were used to analyze the research question for this study. Data collected through the online Qualtrics survey software was organized and Minitab analysis software was used to calculate mean scores, standard deviations and statistical significance. Findings from the study, including pre-and-post comparisons from the professional development component and the implementation component of the study, were analyzed using Analysis of Variance (ANOVA). ANOVA was selected as the statistical technique because the study contained quantitative means of three independent groups. If the calculated F-scores resulted in a statistically significant finding, the post-hoc Tukey Simultaneous Tests for Differences of Means was conducted to further investigate which set of scores contributed to the statistical significance.

Additionally, as the data collection period for this study began during the 2015-2016 school year and continued through the 2016-2017 school year, and given that many teachers changed districts or schools, left the teaching profession, changed the grade level they were teaching, or completed the survey incorrectly, there was a high rate of attrition between those taking the first round of surveys and the third round of surveys. Additionally, when the data from the surveys was collected, some data cleaning had to be performed to remove data of participants that only partially completed the survey or to remove data from participants that had taken the survey twice. Of the original 105 teachers that completed the initial survey in March of 2016, only 32 (30.5%) completed the survey all three times ending in May of 2017. Therefore, in order to establish greater confidence in the data collected during this research study, data was analyzed in multiple ways.

First, data was analyzed using the "linked" data of those teachers (n=32) that were able to take the survey all three times which enabled the groups to be compared. F-scores were calculated and p-values were determined to investigate if the variances between the group means for each of the instances of the surveys were statistically significant. While linking the data resulted in a much smaller n-size, an n-size of 32 enabled researchers to meet the general rule-of-thumb of 30 sets of data often used in in tests of statistical significance involving t-tests and ANOVA (Guenther, 1981).

Because the sample size for the "linked" data was fairly low, n=32, it was decided to also look at the data collected from the entire sample population to see whether those results supported those of the "linked" surveys. In this study, group data included all participants that took the survey during each of the distributions of the survey. F-scores were calculated and p-values were determined to investigate if the variances between the group means were statistically significant. The number of teachers taking the survey each of the three distributions were: Take #1: n=105, Take #2: n=79, Take #3: n=121. Samples sizes are varied because the BSEEE-T instrument was emailed to all participants by school administrators and due to timing and follow-up by school administrators, the number of responses varied.

Finally, in addition to calculating and analyzing “total” mean scores for efficacy and beliefs, mean scores from the nine individual “efficacy” items and the individual nine “beliefs” items were also calculated to more closely investigate teacher responses for the efficacy and beliefs constructs and to look for interesting response patterns in the individual data. The findings from these individual items allowed researchers, professional development providers and administrators to more closely examine teachers’ responses to specific items regarding beliefs and efficacy when teaching engineering content in their elementary–level classrooms.

4 FINDINGS

4.1 Findings

The purpose of this study was to investigate how teachers' perceptions of their own teaching engineering self-efficacy and their beliefs about the importance of elementary-level engineering teaching change in response to professional development in STEM education and the long-term implementation of engineering-related activities into their classroom as measured by the Beliefs and Self-Efficacy in Elementary Engineering-Teachers Scale (BSEEE-T). Specifically, will scored responses from a pre-professional development survey taken by teachers participating in an engineering-related professional development differ from post-professional development survey scores from these same teachers on the following:

1. Beliefs about the importance of teaching engineering content at the elementary level.
2. Confidence in the ability to teach engineering concepts at an elementary school level (Teaching Engineering Self-efficacy).

Furthermore, will the magnitude of any difference between the mean score of the pre and post survey be large enough to be considered statistically significant?

4.2 Findings Relevant to Research Question

4.2.1 Beliefs/Efficacy

Self-efficacy refers to an individual's confidence to competently demonstrate capacity within a specific subject area or task. If a teacher is not confident in their ability to both understand and teach specific content, they are often likely to communicate to their students the content area is of less importance. Directly related to self-efficacy, beliefs may be looked at as the gateway to how a teacher communicates the importance of a subject or task to her students. Furthermore, beliefs help drive (or minimize) a teacher's enthusiasm for teaching a particular topic. Data collected on teachers' teaching engineering self-efficacy and beliefs about the importance of teaching engineering at the elementary level are presented below. Both linked and group-level data from three administrations of the BSEET-T are presented. Using the BSEET-T, researchers had the teachers rate statements relating to belief and self-efficacy on a Likert 6-point scale. The Likert scale was as follows: Strongly Disagree – 1, Disagree – 2, Somewhat Disagree – 3, Somewhat Agree – 4, Agree – 5, Strongly Agree – 6. The lower the Belief score, the less the teachers believe that teaching engineering is an important subject in the elementary schools. The lower the self-efficacy score, the less confident the teachers feel in their ability to teach engineering as a subject in the elementary schools.

4.2.2 Linked Data

In order to investigate a common group of teachers' beliefs and self-efficacy over time, data from those teachers who took the BSEEE-T at all three administrations was investigated. The linked data in Table 4-1 and Figure 4-1 below summarize the means collected from all three instances of the BSEEE-T instrument.

The mean scores for beliefs construct started at 5.29 at Take 1, peak at 5.37 at Take 2, and then lower slightly to 5.33 at Take 3. It was interesting to note that the teachers' beliefs scores were initially quite high to begin with (5.1 out of a possible 6) meaning teachers "agree" to "strongly agree" that they believed teaching engineering at the elementary level was important. This may have been a strong reflection that teachers had been influenced by a large national and local emphasis on STEM curriculum. For several years previous to this research study, there has been a growing emphasis of STEM-related curriculum in the Alpine School District and it would appear that teachers were influenced to believe that engineering is an important topic in the elementary schools.

Looking at Figure 4.1, it is interesting to note that the mean scores for teaching engineering efficacy rose at a higher rate than the increases in mean scores for teacher beliefs. The mean score for efficacy started at 3.998 at Take 1, rose to 4.747 at Take 2, and again rose slightly to 4.781 at Take 3. While beliefs scores were fairly high initially, teachers confidence in their ability to teach engineering-related content was much lower in that they "somewhat disagree" to "somewhat agree" that they were confident in their ability to teach engineering content.

To investigate whether these findings were statistically significant, a test for analysis of variance (ANOVA) was run using the following method and hypothesis: H_0: All means are equal. H_a: At least one mean is different. The results are shown in Table 4-1. When comparing the beliefs mean, the p-value=0.7873 suggesting that we have a 79% probability that the observed information would occur if the null hypothesis (all means equal) were true. When comparing the efficacy mean, the p-value<0.0001 suggests that we have less than 1 out of 10,000 chance that the observed information would occur if the null hypothesis (all means equal) were true. Upon further examination of the efficacy means and the Tukey method of comparison, it was found that there was a statistically significant difference between the mean scores between Take 2 - Take 1 and also Take 3 - Take 1, but not between Take 3 and Take 2 (adjusted p-value=0.9775). The findings, especially regarding teachers' confidence in their ability to teach engineering concepts at an elementary level are statistically significant and represent a major finding in this study.

Table 4-1: Linked Data Means

Beliefs			
N=32			
	Mean	*StDev*	
Take 1*	5.29340	0.52780	
Take 2**	5.37431	0.46788	
Take 3***	5.33030	0.39937	
Analysis of Variance			
Source	*DF*	*F-Value*	*P-Value*
Take	2	0.24	0.7873
Error	93		
Total	95		

Efficacy			
N=32			
	Mean	*StDev*	
Take 1*	3.9983	0.7547	
Take 2**	4.7474	0.5974	
Take 3***	4.7813	0.6364	
Analysis of Variance			
Source	*DF*	*F-Value*	*P-Value*
Take	2	14.12	<0.0001
Error	93		
Total	95		
Tukey Simultaneous Tests for Differences in Means			
Difference of Levels	*Difference of Means*	*95% CI*	*Adjusted P-Value*
Take 2-Take 1	0.7491	(0.3522, 1.1460)	<0.0001
Take 3-Take 1	0.7830	(0.3861, 1.1799)	<0.0001
Take 3-Take 2	0.0339	(-0.3630, 0.4307)	0.9775

*Pre-Professional Development
**Post-Professional Development and Pre-Implementation
***Post-Implementation

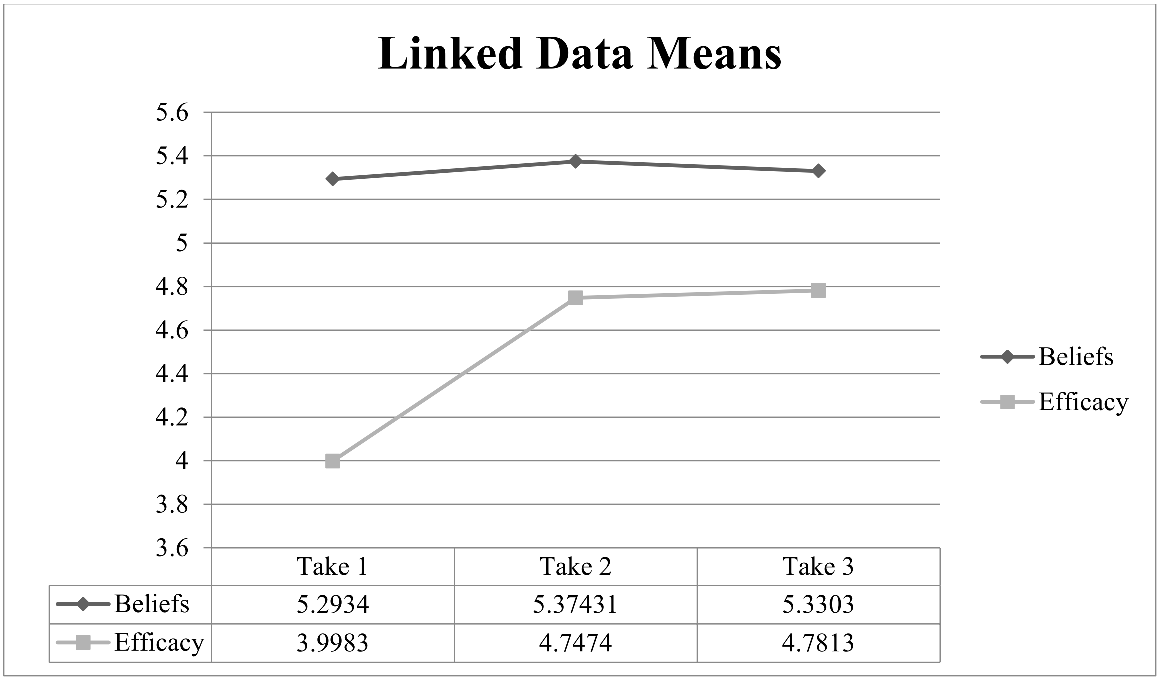


Figure 4-1: Linked Data Means

The data presented in Table 4-1 and Figure 4-1 would indicate that after a week-long professional development both the teachers' belief scores and their teaching engineering self-efficacy scores were much higher. The impact of the professional development was quite positive on the teachers' beliefs and self-efficacy but it is interesting to note that after implementing the engineering activities during a school year the belief mean score for Take 3 took a slight dip. The data from the three administrations would indicate that the teachers were very positive after participating in the professional development but the reality of implementing the activities in their classroom resulted in a slight dip in belief scores but that efficacy scores continued to rise but not enough to be considered statistically significant. It should be noted, however; that these post-implementation scores were still higher than or equal to the scores of the pre-professional development (Take 1).

4.2.3 Group Data

Given that the sample size for the "linked" data was fairly low, n=32, it was decided to compare the linked data to the data collected from the entire sample population to investigate whether the results supported each other. The number of total teachers taking the survey for each of the three distributions were: Take #1: n=105, Take #2: n=79, Take #3: n=121. F-scores were calculated and p-values were determined to investigate if the variances between the group means on the various takes of the survey were statistically significant.

Table 4-2: Group Data Means

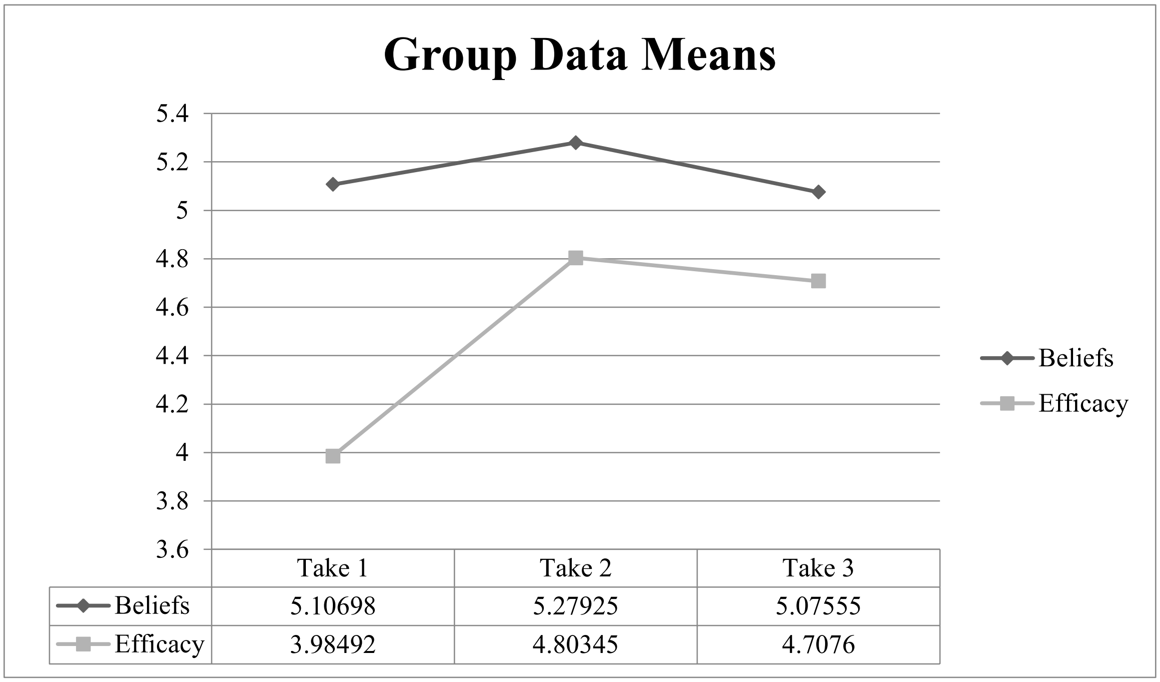
Beliefs		
	Mean	*StDev*
Take 1 N=105	5.10698	0.59181
Take 2 N=79	5.27925	0.53939
Take 3 N=121	5.07555	0.70090

Analysis of Variance			
Source	*DF*	*F-Value*	*P-Value*
Take	2	2.81	0.0620
Error	302		
Total	304		

Efficacy		
	Mean	*StDev*
Take 1 N=105	3.98492	0.73883
Take 2 N=79	4.80345	0.57396
Take 3 N=121	4.70760	0.61963

Analysis of Variance			
Source	*DF*	*F-Value*	*P-Value*
Take	2	47.30	<0.0001
Error	302		
Total	304		

Tukey Simultaneous Tests for Differences in Means			
Difference of Levels	*Difference of Means*	*95% CI*	*Adjusted P-Value*
Take 2-Take 1	0.81853	(0.59111, 1.04594)	<0.0001
Take 3-Take 1	0.72268	(0.51902, 0.92633)	<0.0001
Take 3-Take 2	-0.09585	(-0.31672, 0.12502)	0.5669



	Take 1	Take 2	Take 3
Beliefs	5.10698	5.27925	5.07555
Efficacy	3.98492	4.80345	4.7076

Figure 4-2: Group Data Means

In Table 4-2 and Figure 4-2 the mean scores for the three takes of the BSEEE-T instrument are summarized. Take 1 was collected prior to the professional development. Take 2 was collected at the beginning of the 2016-17 school year. Take 3 was collected at the end of the 2016-17 school year. In Figure 4-2, it can be noted that the patterns for both beliefs and efficacy are similar in that the mean scores were lower for Take 1 at 5.11 for Beliefs and 3.98 for Efficacy, then peak for Take 2 at 5.28 for Beliefs and 4.80 for Efficacy, and then lower slightly for Take 3 at 5.08 for Beliefs and 4.71 for Efficacy. As was observed in the linked data previously, the beliefs mean scores for the grouped data were quite high to begin with in that teachers reported that they strongly agreed that they believed that teaching engineering content at the elementary level was important. The mean scores for efficacy for the grouped data were also similar to the mean scores in the linked data in that teachers were less confident in their abilities to teach engineering-related content in an elementary classroom setting but that their confidence increased dramatically between Take 1 and Take 2. The main difference between the linked data and the grouped data relative to efficacy is that while the mean scores for the linked data increased slightly between take 2 and Take 3, the mean scores for the grouped data slightly decreased between Take 2 and Take 3.

To determine if the variance in these mean scores was statistically significant, a test for analysis of variance (ANOVA) was run using the following method and hypothesis: H_0: All means are equal. H_a: At least one mean is different. The results are shown in Table 4-2. When comparing the "beliefs" mean, the F-Score (2.81) and resulting p-value=0.0620 suggests a 6% probability that the observed information would occur if the null hypothesis (all means equal) were true. When comparing the "efficacy mean", the F-Score (47.30) and resulting p-value<0.0001 suggests a less than 1 out of 10,000 chance that the observed information would occur if the null hypothesis (all means equal) were true. Upon further examination of the efficacy means and the Tukey method of comparison, it was found that there was as statistically significant difference between the means between Take 2 - Take 1 and also Take 3 - Take 1, but not between Take 3 and Take 2 (adjusted p-value=0.5669). The findings, especially regarding teachers' confidence in their ability to teach engineering concepts at an elementary level are statistically significant, represent a major finding in this study and help support the findings from the linked data presented earlier.

4.2.4 Individual Item Means

In addition to the calculation of the total mean scores for both efficacy and beliefs, the mean scores for each of the nine "efficacy" individual items and the nine "beliefs" individual items were calculated. The findings from these individual items allowed researchers, professional development providers and administrators to more closely examine teachers' responses to specific items regarding beliefs and efficacy when teaching engineering content in their elementary–level classrooms.

4.2.5 Individual Efficacy Items

Table 4-3: Individual Item Means: Efficacy

Individual Items: Efficacy		Take 1	Take 2	Take 3
E1	I believe that I have the requisite science skills to integrate engineering content into my class lessons.	3.9375	4.59375	4.70967742
E2	I can explain engineering concepts well enough to be effective in teaching engineering.	3.15625	4.4375	4.58064516
E3	I believe that I have the requisite math skills to integrate engineering content into my class lessons.	4.71875	5	5.03225806
E4	I can explain how engineering concepts are connected to daily life.	4.09375	5.15625	5
E5	I can recognize and appreciate the engineering concepts in all subject areas.	4.21875	4.96774194	4.61290323
E6	I can teach engineering as well as I do most other subjects.	3.35483871	4.03225806	4.19354839
E7	I can describe the process of engineering design.	3.625	5.12903226	5.12903226
E8	My current teaching situation lends itself to teaching engineering concepts to my students.	4.80645161	4.77419355	4.83870968
E9	I can create engineering activities at the appropriate level for my students.	4.125	4.70967742	4.90322581

Table 4-3 lists each individual efficacy construct item with the corresponding mean for Take 1, Take 2, and Take 3 for the "linked" data. First, it is important to note that all of the individual items had significant gains in mean scores from Take 1 to Take 2. This is not surprising given that the combined mean score averages in Table 4-1 and 4-2 were determined to be statistically significant in both the linked and grouped data. What is interesting to researchers, administrators and developers of professional development, is that during the implementation phase of the research study, the efficacy mean scores for each of the items slightly improved or remained constant. While these gain scores are not statistically significant, it is important to see that given the rigors of implementing a subject as time intensive and difficult as engineering into their course curriculum, teachers' confidence in their abilities did not diminish but rather slightly improved. It would be interesting to collect longitudinal self-efficacy data on these same teachers two or three years into implementation when they have had a chance to address issues related to implementing a new curriculum.

When comparing the Take 1 individual "efficacy" means, the findings indicate that items E2), "I can explain engineering concepts well enough to be effective in teaching engineering" (3.15625) and E6), "I can teach engineering as well as I do most other subjects" (3.35483871), had the lowest pre-professional development means. Given that these items directly address the teachers' confidence to teach engineering concepts, it is interesting to note that teachers initially reported the lowest scores on these two items. Engineering is a new and unknown subject in the K-12 curriculum and these results would indicate that this sample of elementary teachers are initially not confident in their ability to teach engineering concepts. Note that these two items had among the largest gain scores of any of the individual items when compared to Take 2 and that these mean scores continued to improve after implementation (Take 3). Despite their initial lack in confidence, participation in professional development and implementation of engineering activities into their classrooms had a significant effect on the teachers reported teaching engineering self-efficacy.

Another interesting finding is to see that teachers reported belief that they had the requisite science (Item E1) and math (Item E3) skills improved significantly between Take 1 and Take 3.

From the findings of this study, it would appear that one of the possible outcomes of an integrated STEM curriculum which includes engineering experiences is the potential positive impact on teachers' perceptions of their science and math skills.

Finally, it should be noted that there was a negative gain on individual item E8), "My current teaching situation lends itself to teaching engineering concepts to my students" (-0.0322581). Administrators and developers of professional development should further investigate this negative finding to address potential issues related to teachers individual teaching situations such as non-teaching demands of teacher time, the quality of the classroom set-up in regards to teaching hands-on activities and other classroom conditions. This data can be used as a formative assessment to guide what aspects are going well within the professional development and possible areas of concern.

4.2.6 Individual Beliefs Items

Table 4-4 lists each individual beliefs construct item with the corresponding mean for Take 1, Take 2, and Take 3 for the "linked" data. When comparing the Take 1 individual "beliefs" means, only two of the items did teachers report that they did not agree (a mean score less than five) on the importance of teaching engineering at an elementary school level. These two items were B3), "Engineering is a 21st century skill that is as important as "the basics" (Reading, Writing, Arithmetic)" (4.96875); and B6), "Engineering concepts should be taught much more frequently in elementary school" (4.9375). It would appear that while the teachers in this study generally had positive beliefs about the importance of teaching engineering at the elementary level, they are less likely to consider engineering part of the basics and that it should be taught more frequently. This is not a surprising finding given that engineering is not part of the core subjects, such as literacy, math and science, which are tested by the Utah State Board of Education.

Table 4-4: Individual Item Means: Beliefs

Individual Items: Beliefs		Take 1	Take 2	Take 3
B1	I am interested in learning more about teaching engineering through in-service professional development.	5.40625	5.1875	5.4516129
B2	Engineering concepts should be taught to elementary school students.	5.4375	5.375	5.70967742
B3	Engineering is a 21st century skill that is as important as "the basics" (Reading, Writing, Arithmetic).	4.96875	5.25	5
B4	Providing more in-class engineering activities would enrich the overall learning of my students.	5.5	5.5625	5.38709677
B5	Engineering content is an important part of the new science standards.	5.13793103	5.46875	5.23333333
B6	Engineering concepts should be taught much more frequently in elementary school.	4.9375	5.25806452	5
B7	Engineering content and principles can be understood by elementary school children.	5.21875	5.38709677	5.48387097
B8	I would like to improve my ability to teach my students to understand the types of problems to which engineering can be applied.	5.5625	5.48387097	5.4516129
B9	Learning about engineering can help elementary students become more engaged in school.	5.46875	5.5483871	5.41935484

The range of individual "beliefs" mean scores was 0.625. When comparing the differences in individual "beliefs" means from Take 1 and Take 2, the largest gain was item B5), "Engineering content is an important part of the new science standards" (+0.33081897). This finding correlates nicely to the fact that engineering is part of the new national science standards, Next Generation Science Standards (NGSS) (National Research Council, 2013) and demonstrates that teachers are aware of these standards and their implications to teaching.

Alternatively, the following three individual "beliefs" items had a negative gain in means: B1) "I am interested in learning more about teaching engineering through in-service professional development" (-0.21875); B2), "Engineering concepts should be taught to elementary school students" (-0.0625); and B8) "I would like to improve my ability to teach my students to understand the types of problems to which engineering can be applied" (-0.078629). While these mean scores did slightly lower through the implementation phase of the study, and while these findings should be closely investigated by school administrators, it is important to note that in general the responses of the teachers in regard to their beliefs that engineering is an important topic to teach at the elementary level were very positive to begin with and did not lower significantly through all phases of the research study. Because of this, we can conclude that teachers believe that engineering should be taught at the elementary level and that professional development and training should focus on how to implement engineering in existing lesson plans.

5 CONCLUSIONS, DISCUSSION, LIMITATIONS, & RECOMMENDATIONS

5.1 Summary and Discussion Relevant to the Research Question

The research question in this study was to determine if scored responses from a pre-survey taken by teachers participating in an engineering-related professional development would differ from scored responses on two subsequent post-surveys following the professional development and following implementation on the following constructs:

1. Beliefs about the importance of teaching engineering content at the elementary level.
2. Confidence in the ability to teach engineering concepts at an elementary school level (Teaching Engineering Self-efficacy).
3. Furthermore, will the magnitude of any difference between the mean score of the pre- and post survey be large enough to be considered statistically significant?

5.1.1 Summary and Discussion Relevant to Beliefs

Beliefs may be looked at as the gateway to how a teacher communicates the importance of a subject or task to her students. Furthermore, beliefs help drive (or minimize) a teacher's enthusiasm for teaching a topic. The first conclusion in this study was that variance in average total mean scores from the Take 1 (5.293), Take 2 (5.374) and Take 3 (5.330) in regards to teachers beliefs about the importance of teaching engineering content at the elementary school was not statistically significant. This suggests that the changes could have occurred by chance alone.

In this study, it was important to note the teachers' beliefs scores were initially quite high to begin with (5.1 out of a possible 6), meaning teachers indicated "agree" to "strongly agree" that they believe teaching engineering at the elementary level is important. Due to the limitations of the instrument, a ceiling effect may be preventing the scores from increasing to the point where we can be certain that the change did not occur by chance.

This high belief score may be a strong reflection that teachers have been influenced by a large national and local emphasis on STEM curriculum. Further, while the teachers in this study generally had positive beliefs about the importance of teaching engineering at the elementary level, an investigation of the individual nine beliefs items from the survey indicated that they are less likely to consider engineering part of the basics and that it should be taught more frequently. This is not a surprising finding given that engineering is not part of the core subjects, such as literacy, math and science that are tested by the Utah State Board of Education. Finally, when comparing the differences in individual "beliefs" means from Take 1 and Take 2, the largest gain was related to a statement about the addition of engineering to the new national science standards - Next Generation Science Standards (NGSS) and demonstrates that teachers are aware of these standards and their implications to teaching.

5.1.2 Summary and Discussion Relevant to Efficacy

Self-efficacy refers to an individual's confidence to competently demonstrate capacity within a specific subject area or task. If a teacher is not confident in their ability to both understand and teach specific content, they are often likely to communicate to their students the content area is of less importance.

Survey scores from Take 1 and Take 2 showed an increase in average self-efficacy scores from 3.998 to 4.747. This 0.749 point increase was statistically significant which suggests that this change did not occur by chance alone. Survey scores from Take 2 and Take 3 showed a smaller increase in average self-efficacy scores from 4.747 to 4.781. This 0.034 increase was not statistically significant which suggests that this change could have occurred by chance. One of the major conclusions from this study was that teachers' teaching engineering self-efficacy can be significantly strengthened through participation in a week-long professional development series. Furthermore, while not statistically significant, the implementation of these activities into their classroom can also help improve teachers' confidence in their ability to teach engineering-related activities.

The research conducted here had similar outcomes to that of Nadelson et al. (2013) and Wendt et al. (2015) who also reported a significant increase in teachers' self-efficacy after participation in elementary level engineering-related professional development activities. While the number of linked participants in this study (n=32) was similar to the research study conducted by Nadelson (n=36) this study, the Nadelson study only looked at teachers' indications of self-efficacy immediately before and after the professional development whereas in this study teachers were surveyed five months prior to the professional development and then three months after the professional development. Additionally, participants in this research study were surveyed after the implementation of the engineering-related activities at the end of the school year, whereas no other studies available included teacher indications of self-efficacy after an implementation component.

Each individual efficacy and belief item of the BSEEE-T was investigated and mean scores were analyzed. What is interesting to teachers, administrators and developers of professional development, is that during the implementation phase of the research study, the efficacy mean scores for each of the individual items slightly improved or remain constant. While these gain scores are not statistically significant, it is important to see that given the rigors of implementing a subject as time intensive and difficult as engineering into their course curriculum, teacher's confidence in their abilities did not diminish but slightly improved.

Another interesting finding was that between Take 1 and Take 3 the teachers' indication that they had the requisite science (Item E1) and math (Item E3) skills to teach engineering content in an elementary school classroom improved significantly.

5.2 Recommendations

The following research recommendations are offered for related research in elementary teacher beliefs and self-efficacy:

1. Surveys be distributed on the last day of the professional development training in order to receive more responses. (Four survey administrations were recommended and are being implemented by Alpine School District for subsequent trainings.)
2. Collect implementation data on the linked teachers in this study two or three years into implementation. Investigate how teachers' beliefs and teaching engineering efficacy changed once they have had a chance to address issues related to implementing a new curriculum.
3. Conduct a similar study in another district. There may be a more dramatic increase in scores, especially beliefs as other districts may initially have less of a STEM emphasis.

4. Run a latent growth curve model for the longitudinal analysis. This could be more appropriate than the analysis of variance (ANOVA) and would allow researchers to maximize the data collected rather than limiting to the linked cases (n=32). Latent growth modeling is used to estimate growth trajectory and is used frequently in behavioral science, education and social science research.

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APPENDIX A. BSEET CONSTRUCTS

A.1 Engineering Self-Efficacy Construct

- I believe that I have the requisite science skills to integrate engineering content into my class lessons
- I can explain engineering concepts well enough to be effective in teaching engineering.
- I believe that I have the requisite math skills to integrate engineering content into my class lessons.
- I can explain how engineering concepts are connected to daily life.
- I can recognize and appreciate the engineering concepts in all subject areas.
- I can teach engineering as well as I do most other subjects.
- I can describe the process of engineering design.
- My current teaching situation lends itself to teaching engineering concepts to my students.
- I can create engineering activities at the appropriate level for my students.

A.2 Engineering Beliefs Construct

- I am interested in learning more about teaching engineering through in-service professional development.
- Engineering concepts should be taught to elementary school students.
- Engineering is a 21st century skill that is as important as "the basics" (Reading, Writing, Arithmetic).
- Providing more in-class engineering activities would enrich the overall learning of my students.
- Engineering content is an important part of the new science standards.

- Engineering concepts should be taught much more frequently in elementary school.
- Engineering content and principles can be understood by elementary school children.
- I would like to improve my ability to teach my students to understand the types of problems to which engineering can be applied.
- Learning about engineering can help elementary students become more engaged in school.