The Differential Impact of Two Engineering Professional Development Programs on Elementary Teachers' Engineering Teaching Efficacy Beliefs

Subject/Problem

The Next Generation Science Standards (2013) puts special emphasis on engineering for K-12 science education and integrates engineering practices into science inquiry practices. Although teachers are expected to engage their students in engineering practices, especially elementary teachers do not have sufficient experience and knowledge in teaching engineering design process and supporting their teaching with reflective discussions on the engineering design process (Cunningham & Carlsen, 2014; Hsu et al., 2011; Katehi, Pearson, & Feder, 2009). Teachers' self-efficacy beliefs about their capabilities to achieve the desired expectations with regard to students' learning has shown to be influential on their instructional decisions and practices (Bandura, 1997; Betoret, 2006; Mojavezi & Tamiz, 2012; Wolters & Daugherty, 2007). Therefore, it can be assumed that elementary teachers need to improve their engineering teaching efficacy beliefs before they integrate engineering design process to their science teaching.

Several studies developed professional development programs to improve teachers' knowledge and confidence about teaching engineering (e.g., Duncan, Diefes-Dux, & Gentry, 2011; Maeng et al., 2017; Phelps et al., 2009). Phelps et al. (2009), for instance, examined the influence of PD program on teachers' beliefs about integrating engineering in their lessons. Analysis based on Engineering Education Beliefs and Expectations (EEBEI) instrument indicated that PD program was found to be successful in improving teachers' knowledge and beliefs about teaching engineering. Maeng et al. (2017) also designed PD program in which upper elementary teachers engaged in Engineering Design (ED) tasks and designing problem-based learning (PBL) units to integrate ED in science education. At the end of the program, it was observed that teachers successfully integrated ED task into their science lessons. In addition, teachers provided opportunities for their students to engage in open-ended ED tasks.

Previous research on self-efficacy beliefs suggested that PD programs could significantly improve personal engineering teaching efficacy beliefs but they did not significantly improve engineering teaching outcome expectancy beliefs (e.g., Lakshmanan et al., 2011; Posnanski, 2002). Our own research (Authors, 2017) also supported these findings. We (Authors, 2017) developed a 3-day PD program in which elementary teachers are engaged in designing a solution to an engineering design problem (soda can crusher design challenge). We aimed to improve elementary engineering teaching efficacy beliefs and help them teach engineering design process as described in the NGSS. We used a modified version of Science Teaching Efficacy Belief Instrument (STEBI) developed by Enochs and Riggs (1990) to measure Personal Engineering Teaching Efficacy (PETE) and Engineering Teaching Outcome Expectancy (ETOE). At the end of the PD program, we found significant changes in elementary teachers' confidence in their own engineering teaching ability (personal engineering teaching efficacy beliefs-PETE) but we did not find any significant change in elementary teachers' belief that student learning can be influenced by effective engineering instruction (engineering teaching outcome expectancy).

Similarly, Posnanski (2002) conducted a study of 43 elementary teachers participating in 32-week professional development program to examine the influence of the program on their self-efficacy beliefs. At the end of the PD, it was found that teachers' personal science teaching efficacy was positively influenced by the PD while significant improvement was not found in their science teaching outcome expectancy beliefs.

Our own research and the relevant literature led us to think that engaging elementary teachers in engineering design activities is necessary but not sufficient to improve their engineering teaching outcome expectancy beliefs. We hypothesized that elementary teachers should explore the available engineering lessons from credible sources, modify the lessons based on their specific grade level, and to teach them before they improve their engineering teaching outcome expectancy beliefs. We think that supporting elementary teachers' pedagogical content knowledge about teaching engineering would be instrumental in helping them improve their engineering outcome expectancy beliefs. Therefore, the purpose of this study is to explore to what extent supporting elementary teachers' PCK about teaching engineering would improve their beliefs that students' engineering learning can be influenced by effective engineering instruction.

Procedure

Participants

The study included 49 in-service elementary teachers from a large public school district in Western United States. 30 elementary teachers attended a 3-day professional development program in Summer 2016 while 19 teachers participated in a 5-day program in Summer 2017. Participants' ages ranged between 24 to 65 years with a mean of 44 years. Teachers had different teaching experiences ranging from 1.5 to 26 years and they took several college level science and engineering related courses (0-10).

Engineering Professional Development Programs

Summer 2016 professional development program (PDP) lasted for 3 days (6 hours per day). The PDP started with a 30-minute lecture about the place of engineering in the NGSS. The first author introduced participants to grades K-2 and 3-5 engineering design performance expectations. This relatively short lecture followed by a 1-hour lecture aimed to introduce the engineering design process with a real life example to elementary teachers. A mechanical engineering professor delivered the second lecture. The professor used constructing a soda can crusher as a real life example to talk about the engineering design process. The professor explicitly talked about the phases of engineering design, the role of creativity during the design process, and the fact that there is no single best design for a given engineering design challenge. The professor also emphasized how market needs influence the engineering design process during the lecture. He explained that engineers need to consider certain factors such as what is currently available in the market, who is willing to buy a soda can crusher, and what qualities (cost, ease of use, storage space, aesthetics, reliability, portability) people are expecting from a soda can crusher.

We told our participants that they would experience the engineering design process by constructing soda can crushers in groups of 3 or 4. Participants went through the entire engineering design process similar to real engineers. They conducted a small needs analysis by asking people around them whether they would purchase a soda can crusher, what qualities they are looking for in a soda can crusher, and how much money they would spend on a soda can crusher. They also searched for the commercially available soda can crushers in the market. Participants in groups of 3 or 4 designed soda can crushers on paper first, and then they constructed, tested, and improved their designs by considering criteria such as ease of use, reliability, portability, aesthetics, and storage space needed. Participants constructed their soda can crushers in a fully equipped university mechanical engineering shop under the supervision of mechanical engineering graduate students. After groups finalize their designs, each group wrote a script and shot a 2 or 3 minutes long video commercial for their product. Participants as a whole class watched the video commercials one by one and made a decision whether they would buy the product in the video commercial by considering the criteria mentioned above. Finally, participants wrote a report by comparing and contrasting their designs to others in light of the five criteria: ease of use, reliability, portability, aesthetics, and storage space needed.

Summer 2017 professional development program (PDP) lasted for 5 days (6 hours per day). The first three days of Summer 2017 PD program were exactly the same as Summer 2016 PD program except that participants in Summer 2017 designed trash grabbers instead of soda can crushers. During the fourth day of PD program, participants explored elementary level engineering lessons/activities from Science & Children journal and NASA website. Teachers were grouped according to their grade level and each group included three or four teachers. As a group they selected an engineering lesson, they examined the lesson using NGSS EQUiP rubric, modified the lesson and co-taught the lesson during the fifth day of the PDP. Each group received feedback from other groups and the science education professor at the end their teaching.

Data Collection

In our research, we used a 5 point Likert type scale (1-Strongly Disagree, 2- Disagree, 3- Neither Agree nor Disagree, 4- Agree, 5- Strongly Agree) ETEBI instrument to investigate in-service elementary science teachers' engineering teaching efficacy beliefs. ETEBI is the modified version of the 23 item Science Teaching Efficacy Beliefs Instrument (STEBI-A) (Enochs and Riggs, 1990) to measure participants' engineering teaching efficacy beliefs. We replaced the word 'science' with 'engineering' in each item to create the ETEBI. Data were collected through ETEBI instrument and is used to measure elementary teachers' engineering teaching efficacy beliefs in a pre- and post professional development fashion.

Data Analysis

Engineering teaching efficacy beliefs data were analyzed using Statistical Package for the Social Science (SPSS 25.0) for MacOS. Means, standard deviations, maximum and minimum scores for two subscales (PETE and ETOE) were measured for both groups . Cronbach's alpha values for two subscales were also measured (see Table 1 and Table 2). Two paired samples t-tests were executed to investigate the impact of professional development in elementary teachers PETE and ETOE scores for each group.

Analyses and Findings

We reported two subscales for the ETEBI instrument: Personal Engineering Teaching Efficacy (PETE) and Engineering Teaching Outcome Expectancy (ETOE). PETE is elementary teachers' confidence in their own engineering teaching ability, while ETOE is elementary teachers' belief that student learning can be influenced by effective engineering instruction.

Table 1. Means, standard deviations, maximum and minimum scores, and subscale reliability for 3-day PD (Soda Can Crusher Challenge) in Summer 2016

Science teaching efficacy beliefs		Mean	SD	Max.	Min.	α	t
PETE	Pre	39.53	9.58	58	19	0.91	-7.89**
	Post	49.90	6.61	62	37	0.87	
ETOE	Pre	37.43	5.78	50	16	0.89	-0.46
	Post	37.80	7.32	49	18	0.90	

*p<.05, **p<.01

Table 2. Means, standard deviations, maximum and minimum scores, and subscale reliability for 5-day PD (Mechanical Grabber Challenge) in Summer 2017

Science teaching efficacy beliefs		Mean	SD	Max.	Min.	α	t
PETE	Pre	46.79	8.54	62	35	0.91	-4.74**
	Post	53.95	7.43	64	40	0.91	
ETOE	Pre	35.10	5.22	44	26	0.80	-3.36**
	Post	37.79	4.99	48	27	0.80	

*p<.05, **p<.01

Our paired sample t-test results revealed that for the 3-day PD PETE ($t = -7.89$, $p < 0.01$) beliefs significantly improved at the end of the professional development program, but ETOE ($t = -0.46$, $p = 0.64$) beliefs did not change at the end of the professional development program. However, for the 5-day PD, both PETE ($t=-4.74$, $p<0.01$) and ETOE ($t=-3.36$, $p<0.01$) scores showed significant improvements.

Contribution

This study makes a contribution to the literature because it successfully adapted an existing science teaching efficacy instrument to measure changes in elementary teachers' engineering teaching efficacy beliefs. Future studies assessing in-service elementary teachers' engineering teaching efficacy beliefs can benefit from this adaption. Our results indicated that our participants in a 3-day PD program improved their personal engineering teaching efficacy (PETE) beliefs but they did not improve their engineering teaching outcome expectancy (ETOE) beliefs. These results suggest that PD programs should support teachers' PCK about teaching engineering to be able to improve their engineering teaching outcome expectancy beliefs as well.

General Interest

We think that this study will be of interest to NARST members who are particularly interested in engineering education.

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