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Perceptions of Teaching Safer Engineering Practices: Comparing the Influence of Professional Development Delivered by Technology and Engineering, and Science Educators

Abstract

The release of the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013a) raised concerns regarding elementary school science educators' preparation to adequately teach engineering practices using potentially hazardous engineering tools and materials[1] (Love, 2014, 2015b; NSTA, 2016; Roy, 2012, 2013, 2014a, 2014b, 2015). This study employed a concurrent quasi-mixed methods design (Teddlie & Tashakkori, 2006) to examine the safety perceptions of 131 elementary teachers among four professional development (PD) implementation sites across a southern state. The PD was taught by science education experts at all sites except for one, which was collaboratively delivered by science, and technology and engineering (T&E) education[2] experts. The goal of this study was to compare the differences in safety perceptions among each PD site to examine if the collaborative delivery of PD by T&E educators was associated with differences in participants' self-efficacy beliefs and expected outcomes toward safer use of engineering tools and materials in science instruction. Participants at the collaborative site reported significantly greater safety self-efficacy gains and a greater overall safety awareness than participants at the other sites. This study provides implications to enhance elementary teachers' awareness and self-efficacy toward safer use of engineering tools and materials within science curricula through collaborative preparation efforts with T&E educators.

Introduction

With the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013a) raising engineering design to same substantive level as scientific inquiry (Love & Deck, 2015, NSTA, 2016) there have been concerns about the preparation of science educators to adequately teach engineering content and practices (Buchanan, 2013; Hosni, 2013; Nadelson & Farmer, 2012). Of greater concern is the expectation for science educators to teach engineering practices with little to no training on safer use of hazardous hand and power tools needed to construct authentic engineering design solutions (Love, 2014, 2015b; Roy, 2012, 2014a, 2014b, 2015). For many years researching and teaching safer practices involving engineering tools and materials[1] has been the domain of technology and engineering (T&E) education[2] (formerly known as industrial arts, industrial technology education, and technology education). Most T&E teacher preparation programs require students to complete methods and laboratory design/management coursework that specifically addresses engineering tool and material safety topics (Litowitz, 2014). The safer use of engineering tools and materials has also been a core component of T&E education instructional standards (ITEA/ITEEA, 2000/2002/2007; Gunter, 2007; Love, 2014) and program standards for over a decade (ITEA/ITEEA, 2003). Despite the cross-disciplinary nature of T&E and science education standards, and the wealth of expertise T&E education has developed relative to engineering tool and material safety, there have been few documented collaborative efforts among these fields to deliver safer engineering practices now mandated by the NGSS (Love 2014, 2015b; Roy, 2014a).

One setting that provides the optimal opportunity to collaboratively teach safer crosscutting concepts (e.g., science content and engineering practices) is the elementary grade level (ITEA/ITEEA, 2000/2002/2007, pp. 7-8). Numerous resources (PDE, 2002; Roy, 2013; Weaver, 2017) have indicated that engineering tools such as hand crank drills, clamps, files, and hacksaws are appropriate for students at this grade level. Roy (2013) asserted that such engineering tools are not only appropriate at this level, but necessary for elementary students to solve simple design problems as called for by the NGSS:

[1] In this article engineering tools and materials encompass hand and power tools (e.g., hammer, screw driver, coping saw, cordless drill) and fabrication materials such as woods, metals, and plastics.

Keywords: School laboratory safety, science education, technology and engineering education, professional development, mixed methods

[2] T&E education is "concerned with the broad spectrum of technology, which encompasses but is not limited to, such areas as: design, making, problem solving, technological systems, resources and materials, criteria and constraints, processes, controls, optimization and trade-offs, invention, and many other human topics dealing with innovation" (Dugger & Naik, 2001, p. 31).

Engineering design in the earliest grades introduces students to 'problems' as situations that people want to change. They can use tools and materials to solve simple problems, use different representations to convey solutions, and compare different solutions to a problem and determine which is best (NGSS Lead States, 2013b, p. 3). (p. 86)

There is an identifiable gap between the expectation for elementary science educators to use engineering tools and materials, and their preparation to safely integrate these into their instruction. Additionally, there is an apparent lack of collaboration among science educators and T&E educators who have developed expertise to safely incorporate engineering tools and materials in instruction. What is not clear is the extent to which collaborative experiences with T&E educators influence elementary science educators' preparation for teaching safer engineering practices. The main goal of this study was to examine the impact of a professional development program (PD) delivered collaboratively by science and T&E education experts on elementary educators' perceptions toward using engineering tools and materials more safely in science instruction.

Review of Literature

There have been a number of white papers and guides recently published with recommendations for safer science, technology, engineering, and mathematics (STEM) laboratory practices. Most notably, the Safety Advisory Board for the National Science Teachers Association (NSTA) published a white paper providing recommendations to help science educators address new safety hazards inherent with engineering practices (NSTA, 2016). They specifically highlighted the importance of hand and power tools to develop engineering solutions, "In many cases constructing models and engaging in engineering design will involve the use of hand and power tools more common to the technology education lab rather than the science laboratory" (NSTA, 2016, p. 4). Moreover, they recommended collaborating with T&E educators to teach safer engineering practices, "Collaboration with the technology education teachers may help science teachers explore better professional practices with regard to tool use. Districts should have standard operating procedures for the use of hand and power tools. These procedures should be developed with the technology education teachers..." (NSTA, 2016, p. 4).

Within their white paper the NSTA Safety Advisory Board also encouraged science teachers to reference the International Technology and Engineering Educators Association's (ITEEA) extensive laboratory safety book (DeLuca, Haynie, Love, & Roy, 2014) that features recommendations and instructional resources for safer engineering practices. This book was a concerted effort between NSTA and ITEEA laboratory safety specialists that NSTA recommended, "Every department office, lab, and shop space should have a copy of this book to use as a handy reference" (Glitzke, 2015, p. 65). In light of these recommendations many science and T&E educators have continued to operate in isolation of each other regarding safer engineering practices (Roy, 2014a).

Prior to ITEEA's laboratory safety book (DeLuca et al., 2014) and the Safety Advisory Board's whitepaper (NSTA, 2016), few researchers had suggested a collaborative approach between science and T&E educators to promote safer cross-disciplinary STEM education learning experiences. Love (2015a) presented examples of innovative strategies for science and T&E educators to make safety instruction more engaging. From a legal perspective Ferguson, Ford, & Bumgarner (2010) presented similarities between rulings in higher education science and engineering laboratory accidents. Love (2013a, 2013b, 2014, 2015b) and Roy (2014a) recommended that science educators, administrators, and teacher preparation faculty follow emerging legal rulings from P-12 T&E laboratory accidents since they had been cited as the precedent in many P-12 science laboratory rulings, and vice versa. Staying current on the latest safety findings from both fields was recommended to inform safer STEM education laboratory policies and limit liability inherent with teaching engineering practices.

There has been a limited amount of research examining the influence of pre and inservice preparation on laboratory safety. Plohocki (1998) found that undergraduate safety training, graduate safety training, and school sponsored inservice sessions did not significantly increase science teachers' safety content knowledge. Many participants in that study indicated they did not feel adequately instructed on science safety and were interested in attending safety workshops. One of the most renowned laboratory safety studies demonstrated that accidents, incidents, and mishaps increased as classroom size and space per student decreased (Stephenson, West, Westerlund, & Nelson, 2003). Additionally, Stephenson et al. found that about one third of participating science teachers did not have adequate safety training or a written safety policy for their laboratory.

Conducting observations to examine science educators' safety practices is a time intensive process. A more feasible method for collecting safety data from a larger sample of educators' is to examine their self-efficacy, which has been found to influence teaching practice (Luft et al., 2011). Bandura (1997) defined self-efficacy as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). Teachers with greater self-efficacy have demonstrated higher expectations not only for themselves, but also for their students (Shidler, 2009). Furthermore, self-efficacy has been linked to instructional quality (Holzberger, Philipp, & Kunter, 2013), and single professional development workshops have been found to influence both teacher efficacy beliefs and student achievement (Fancera & Bliss, 2011; Moolenaar, Sleegers, & Daly, 2012). Therefore, greater self-efficacy toward engineering tool and material safety from a PD experience would be expected to positively influence one's teaching of safer engineering practices.

The literature suggests that the most logical solution to prepare science educators for delivering safer engineering practices is through collaborative experiences with T&E educators (DeLuca et al., 2014; Love, 2013a, 2013b, 2014, 2015b; Roy, 2012, 2014a, 2014b, 2015). However, no prior research exists to substantiate this claim, therefore the following research questions helped guide this study to examine this critical issue.

Research Questions

RQ1: What is the extent of elementary level science educators' prior experience and training related to safer use of engineering tools and materials?

RQ2: To what extent did elementary level science educators' self-efficacy regarding the safer use of engineering tools and materials within their classroom differ when PD was delivered collaboratively by science and T&E education versus only science education experts?

RQ3: To what extent did elementary level science educators' outcome expectancies regarding the safer use of engineering tools and materials within their classroom differ when PD was delivered collaboratively by science and T&E education versus only science education experts?

RQ4: To what extent did elementary level science educators' overall engineering tool and material safety awareness differ when PD was delivered collaboratively by science and T&E education versus only science education experts?

Table 1. Participant Demographics

Characteristic	n (%)
Gender	
Male	11 (8)
Female	120 (92)
Ethnicity	
White	105 (80)
Hispanic	2 (2)
Black	20 (15)
White/Black	1 (1)
White/ Hispanic/ Black	1 (1)
White/ Hispanic	2 (2)
Grade Level Taught	
1st grade	2 (2)
2nd grade	2 (2)
3rd grade	12 (9)
4th grade	41 (31)
5th grade	66 (50)
6th grade	7 (5)
School Setting	
Rural	28 (21)
Suburban	59 (45)
Urban	40 (31)
Did not identify	4 (3)
Certification Area	
Elem. K-6	92 (70)
Elem. PreK-8	23 (18)
Middle Grades 4-8	9 (7)
Early Childhood PK-3	4 (3)
Biology 7-12	2 (2)
Special Ed K-12	1 (1)

Note. Grade level refers to the grade taught at the time of the PD. Elem. = elementary.

Study Participants

This study was part of a federal grant funded PD project focused on enhancing elementary educators' teaching of science while integrating newly mandated engineering content and practices (NGSS Lead States, 2013b). Participants were grade 1-6 teachers from a southern state and possessed a variety of background experiences. The mean age of participants was 39 years old and the average amount of teaching experience was 10.5 years. Most participants were white (80%) females (92%) who taught fourth (31%) or fifth (50%) grade in a rural school district (45%). Many were certified to teach grades K-6 (71%) or PreK-8 (23%) (Table 1).

Methodology

To better serve teachers from all regions of the state, four distinct university implementation sites offered similar PD experiences. The PD at Sites 2-4 was taught by experienced P-12 educators, teacher preparation faculty members, and graduate students with extensive experience in science education, whereas the PD at Site 1 was taught collaboratively between T&E and science education experts. The PD was an intense four-week experience beginning with one week of sessions focused on increasing teachers' science and engineering content knowledge through hands-on labs and observations of pedagogical strategies modeled by the PD leaders.

During the first week PD instructors at each site engaged participants in the ocean platform engineering design challenge (Love & Deck, 2015) to demonstrate an exemplar lesson for integrating science content and engineering practices at the elementary level. All participants were provided with the same design challenge, materials, and tools; however instructional content and methods regarding safer use of engineering tools and materials was left up to the discretion of the PD instructors at each site. This allowed ample opportunities to compare differences in participants' perceptions toward safer use of engineering tools and materials as a result of the PD. Over the next two weeks participating teachers planned and taught a science camp for students entering grades four through seven. During the fourth and final week of the PD, teachers discussed their experiences from the previous three weeks while working with their site's PD leaders to develop a problem-based learning unit to implement in their classroom during the upcoming school year.

This study utilized a concurrent quasi-mixed methods design (Teddlie & Tashakkori, 2006) that analyzed quantitative pre and postsurvey data along with supplementary open-ended survey questions. The survey questions described in the following section were used to analyze the differences in elementary teachers' self-efficacy and expected outcomes toward safer use of engineering tools and materials in science instruction as a result of the PD. To reduce bias, the researcher was not involved in any aspect of the PD except for providing explicit directions about administering the surveys and analyzing the data. The paper presurvey was administered during the first week of the PD and prior to any lessons involving engineering content. Participants at each site were randomly assigned a number, allowing the researcher to compare the pre and postsurveys during data analyses, and disaggregate the data according to implementation site. During the final week of the PD participants were asked to voluntarily complete the paper postsurvey. Upon receiving the surveys the researcher entered the results into SPSS for statistical analysis. Eight presurveys were removed from the study due to participants failing to voluntarily complete the postsurvey.

Instrumentation

Approval to conduct research using human subjects was obtained from the Institutional Review Board at the University which received the grant to fund the PD. To measure educators' self-efficacy and expected outcomes, the Science Teaching Efficacy Belief Instrument (STEBI) (Enochs & Riggs, 1990) which consists of 13 questions measuring teacher's Personal Science Teaching Efficacy Belief (PSTE), and 10 questions measuring Science Teaching Outcome Expectancy (STOE), was utilized. The STEBI was originally designed to determine the science teaching self-efficacy of elementary teachers, but has been adapted and found reliable for use in various disciplines, such as mathematics and T&E education (Enochs, Smith, & Huinker, 2000; Love & Wells, 2017; Rohaan, Taconis, & Jochems, 2009, 2011). For these reasons the STEBI was deemed suitable to adapt for measuring elementary educators' perceptions about teaching safer use of engineering tools and materials. To modify the instrument items, yet stay true to the original STEBI, the word "science" in all instrument items was replaced with "safer use of engineering tools and materials in science" (Appendix A). The PSTE items (2, 3, 5, 6, 8, 12, 17, 18, 19, 20, 22, 23) were used to measure educators' change in self-efficacy toward safer use of engineering tools and materials, and the STOE questions (1, 4, 7, 9, 10, 11, 13, 14, 15, 16) measured changes in their outcome expectancy for using engineering tools and materials more safely.

The original STEBI instrument was found to be reliable and valid (Enochs & Riggs, 1990), and was later revalidated (Bleicher, 2004). Since the original STEBI questions were slightly revised for this study, Crohnbach's alpha was used to examine the reliability of the instrument items and revealed a high reliability for both presurvey (.807) and postsurvey (.888) questions. Specifically, the presurvey self-efficacy items had an alpha of (.814) while the presurvey outcome expectancy items had an alpha of (.785). The postsurvey self-efficacy items were found to have an alpha of (.885) and the postsurvey outcome expectancy items had an alpha of (.870). These alpha values indicated that the modified instrument items provided reliable measures of participants' self-efficacy and expected outcomes regarding the safer use of engineering tools and materials. Furthermore, face validity of the modified instrument was established among a panel of national science and T&E education safety specialists. This panel consisted of two tenured science teacher preparation faculty members, one cross-disciplinary STEM education expert, the Chief Science Safety Compliance Consultant for NSTA, and the lead author of the revisions to ITEEA's safety book (DeLuca et al., 2014). Panel members provided suggestions until all were in agreement that the structure of the questions were consistent with the original STEBI items, and they accurately examined teachers' safety perceptions in alignment with the NGSS. Once the instrument satisfied the reliability and validity measures it was administered to the participants.

Data Analysis and Findings

The first research question about participants' prior experience and training regarding engineering tools and materials was examined through supplemental presurvey questions and analyzed using descriptive statistics. A large number of participants (65%) reported not using engineering tools or materials in previous courses they taught. In high school, the majority (84%) reported never having taken a course in which they learned how to use engineering tools and materials. Furthermore, most teachers (84%) reported never participating in PD that covered safer use of engineering tools and materials (Table 2).

In the presurvey participants also provided responses to supplemental open-ended questions reporting the extent of their prior experiences with engineering tools and materials. These responses were qualitatively coded into four categories: no, limited, moderate, and extensive prior experience with using engineering tools and materials. Examples of common participant responses for each category are provided in Table 3. Many teachers reported having no (29%) or limited prior experience (37%) with using engineering tools and materials (Table 3).

Table 2. Participants' Prior Coursework Using Engineering Tools and Materials

Experience	n (%)
T&E HS Courses	
0	84 (64)
1	29 (22)
2	11 (8)
3	0 (0)
4	6 (5)
5+	1 (1)

Note. HS = high school.

Research questions two and three were first analyzed using a Kruskal-Wallis test to examine if there was a significant difference among gains in self-efficacy and expected outcome scores among the four sites. Kruskal-Wallis tests were selected due to the non-parametric and ordinal characteristics of the multiple independent samples (Sheskin, 2011). This type of test is used to analyze differences between the medians of three or more independent groups with equal or unequal sample sizes, and does not require the normal distribution of data. The critical *p*-value was set at 0.05 for all analyses conducted in this study. The tests revealed a significant difference (0.011) regarding gains in self-efficacy scores among the four sites, but no significant difference in expected outcome scores (0.086) (Table 4).

Since the Kruskal-Wallis test identified a significant difference among self-efficacy ratings across the four sites, this prompted the use of Mann-Whitney U tests to separately analyze differences among Site 1 which was led collaboratively by science and T&E education experts, and each of the other PD sites facilitated solely by science education experts. The Mann-Whitney U analysis was deemed suitable to test for significant differences

Table 3. Participants' Prior Experience Level Using Engineering Tools and Materials

Experience Level	n (%)	Examples
None	38 (29)	No prior experiences listed by participants.
Limited	48 (37)	Basic non-power tools at home for craft activities or furniture assembly: glue gun, hammer, saw, screw driver, car jack, pressure gauge, etc.
Moderate	23 (18)	Power and non-power tools to help construct home or student projects: saws, drills, etc.
Extensive	22 (17)	Advanced power tools to design and construct items such as trebuchets, decks, theatrical stages, original furniture: table saw, band saw, scroll saw, circular saw, drill press, sander, nail gun, etc.

among two samples with ordinal data from a non-parametric sample. This type of analysis tests for the mean difference in rank of responses between two independent groups with equal or unequal sample sizes.

The second research question examined to what extent teachers' self-efficacy regarding the safer use of engineering tools and materials differed when PD was delivered collaboratively by science and T&E education versus only science education experts. The p-value among Sites 1 and 2 (0.027) and Sites 1 and 4 (0.014) were less than the alpha of value of 0.05, indicating that the professional development at Site 1 had a significant influence on teachers' self-efficacy to use engineering tools and materials more safely. There was not a statistically significant difference in self-efficacy gains between Sites 1 and 3 (Table 5).

Furthermore, since the Kruskal-Wallis test (Table 4) revealed there was not a statistically significant difference among participants' outcome expectancy scores across all sites, further investigation of each site using Mann-Whitney U tests was not warranted. Therefore, in regards to the third research question, it was determined there was no identifiable difference among participants' outcome expectancies for safer use of engineering tools and materials.

Finally, RQ4 was examined through participants' responses to the supplemental open-ended question on the postsurvey which asked to what extent they believed the PD experience increased their awareness to use engineering tools and materials safer. Their responses were qualitatively coded into three categories and assigned a rating of none (0), somewhat (1), and greatly (2). Participants who believed the PD did not increase their awareness were coded into the none category. Those who felt the PD somewhat increased their awareness of engineering tool and material safety often described experiences such as wearing safety goggles as the most important lesson learned. Teachers who described an increased awareness with using more advanced tools and materials (e.g., dowel rods, wood, plastics, saws, drills, tin snips, etc.) were coded into the greatly increased awareness category. Since the categories were reported as numerical ratings, Mann-Whitney U tests were deemed most appropriate to examine the mean difference in rank responses between two independent samples. The Mann-Whitney U tests revealed that p-values among Site 1 and each of the other PD sites were less than the alpha value of 0.05. This indicated that participants at Site 1 had gained a significantly greater awareness about the safer use of engineering tools and materials than teachers at the other PD sites (Table 6).

Table 4. Differences Among Scores at All Sites

Site	n	df	Median	Mean Rank	Chi-Square	P-value
Self-Efficacy						
1	27	3	8	77.61	11.235	0.011*
2	40	3	5	58.19		
3	36	3	7	77.03		
4	28	3	4	51.79		
Expected Outcomes						
1	27	3	0	68.72	6.605	0.086
2	40	3	1	74.85		
3	36	3	0.5	65.64		
4	28	3	-2	51.20		

Note. * = statistical significance at the 0.05 level.

Limitations of the Study

There are certain limitations of this study that should be considered. Although this research included a large sample of teachers from a southern state, the results cannot be generalized beyond those participating teachers, especially to secondary level science educators at large. It should be acknowledged that 92% of the participants were females and the findings may not be generalizable to male elementary teachers. However, the large percentage of female participants in this study is consistent with national labor force statistics indicating that the majority (78.5%) of elementary and middle school teachers are females (U.S. Department of Labor, 2017). Furthermore, the data reflects the participants' self-reported perceptions regarding safer use of engineering tools and materials, and the analyzed differences were dependent upon the accuracy of their reported scores. It is important to remember that the findings from this study reflect participants' self-reported perceptions and not observed changes in safer practices. It should also be noted that although Mann-Whitney U tests were used to analyze the differences among the collaborative site and each of the other PD sites to account for an unbalanced sample size, as well as an unbalanced number of sites in the collaborative versus non-collaborative groups, the overall findings reflect differences among 27 and 104 total participants at the respective sites.

Discussion and Conclusions

In examining the first research question it is clear that many of the participants

Table 5. Differences of Self-Efficacy Scores Among Sites

Site	(n)	Median	Mean Rank	U	Z	P-value
1	27	8	40.41	367.000	-2.218	0.027*
2	40	5	29.68			
1	27	8	31.83	481.500	-0.063	0.950
3	36	7	32.13			
1	27	8	33.37	233.000	-2.448	0.014*
4	28	4	22.82			

Note. * = statistical significance at the 0.05 level.

had little if any prior experience using engineering tools and materials, and very few completed high school T&E courses where safer use of these items are often learned. Additionally, a large portion of participants reported not using engineering tools or materials in previous courses they taught (65%) and never receiving PD teaching about the safer use of engineering tools and materials (84%). These findings are concerning for students' safety since elementary level science educators are now expected to integrate engineering concepts without the proper, if any, experience using engineering tools and materials in a safer manner. Given this finding that many elementary level science teachers are lacking adequate preparation to safely conduct engineering activities with their students, it would imply that such critical crosscutting concepts are being taught in an unsafe manner or being avoided all together at the expense of students' learning. It is pertinent that teachers at this level receive the proper pre and inservice preparation to provide safer learning environments for the teaching of engineering practices.

The results from the Mann-Whitney U tests examining RQ2 would suggest that when T&E educators collaboratively deliver PD with science educators it does have a significant influence on enhancing elementary teachers' self-efficacy regarding the safer use of engineering tools and materials. As identified in the analyses, Site 1, where T&E educators collaboratively participated in PD, demonstrated significantly greater gains than Sites 2 and 4 where the PD was taught solely by science education experts. While there was no significant difference in the self-efficacy gains between Sites 1 and 3, Site 3 did record a higher mean difference (7.50) than Site 1 (7.33). Despite these overall gains, Site 1 recorded the three greatest increases for individual self-efficacy questions (12, 19, 23) (Appendix B). The scores from these items indicated that participants from Site 1 where T&E educators were present, reported higher gains than participants at other sites regarding their self-efficacy toward teaching students to effectively and safely use engineering tools and materials. The greater total gain at Site 3 demonstrates that science educators can positively influence elementary teachers' self-efficacy regarding safer use of engineering tools and materials to teach science, however the analysis of the open-ended supplemental survey questions examining RQ4 revealed conflicting findings. Given that Site 3 had the highest overall self-efficacy gain, it could be expected that this site would also demonstrate the greatest reported increase in awareness about engineering tools and materials safety. This was not the case (Table 6) as participants at Site 1 reported a significantly greater awareness about the safer use of engineering tools and materials than teachers at Site 3. Specifically, 67% of participants at Site 1 believed the PD significantly increased their safety awareness, whereas only 39% of Site 3 teachers expressed the same belief.

From the qualitative analysis of the supplemental open-ended survey questions in RQ4 it was clear that participants at Site 3 had misconceptions about engineering tool and material safety. This was evident from what many Site 3 participants reported as the most important safety lesson learned – students should wear goggles and gloves. Specifically, multiple teachers stated that if materials are anything other than room temperature water, then goggles must be worn. Not only is this information inaccurate and out of compliance with many state laws (proper eye protection must be worn any time someone in the same room is using any hazardous tool/material/chemical, including liquids of any type) but it also encourages poor laboratory habits. To avoid confusion and encourage consistently safer behaviors, students should be required to wear indirectly vented chemical splash goggles any time hazardous or non-hazardous liquids are present. The fact that many Site 3 participants mentioned this as the most valuable safety lesson learned from their PD experience questions if they truly used engineering tools and materials, or if they predominantly used traditional science tools and materials which were improperly referred to as engineering items. Teachers from other sites recognized that safety goggles were not the only key safety precaution needed when using engineering tools and materials. A Site 4 participant made this distinction when describing the influence that the PD had on their overall safety awareness, "Other than goggles and gloves I did not learn anything about lab safety."

These qualitative findings question if participants at Site 3 fully understood what the postsurvey questions were

Table 6. Differences Among Increased Engineering Tool and Materials Safety Awareness

Site	(n)	Median	Mean Rank	U	Z	P-value
1	25	3	40.22	294.500	-2.893	0.004*
2	39	2	27.55			
1	25	3	37.48	288.000	-2.613	0.009*
3	36	2	26.50			
1	25	3	37.10	97.500	-4.816	< 0.0001*
4	28	1	17.98			

Note. * = statistical significance at the 0.05 level.

referencing in terms of engineering tools and materials despite providing explicit examples in the survey instructions. This misconception could have inflated the reported gains. The data indicated that although Site 3 did show substantial increases in self-efficacy ratings, the science experts at the PD did not adequately emphasize the difference between safer engineering tools and safer science tools. Whereas at Site 1, a greater number of participants mentioned an increased awareness about how to use items such as small saws, hammers, screwdrivers, dowel rods, and other engineering related tools and materials more safely with students. Another plausible explanation for the large self-efficacy increase at Site 3 may be due to postsurvey sensitization in which participants recognized that the postsurvey was assessing gains so they knowingly reported higher scores (Bracht & Glass, 1968).

In regards to the third research question, it was found that the presence of T&E educators at Site 1 was not associated with significant differences in educators' outcome expectancies. All sites recorded positive increases in participants' expected outcomes except Site 4, where participants reported an overall decrease (Appendix B). This indicates that when science educators are delivering PD, they can have an adverse effect on elementary educators' expectations to safely use engineering tools and materials if they do not properly emphasize and demonstrate essential safety concepts. For this reason it is important to ensure that safer engineering practices, beyond simply wearing goggles, are an integral part of science teachers' preparation experiences and are taught in collaboration with a T&E education expert.

The main purpose of this study was to examine if sites where PD was delivered collaboratively by science and T&E education experts differed significantly in regards to elementary educators' perceptions toward using engineering tools and materials more safely in science instruction. Findings indicated that elementary science educators' reported higher perceived engineering tool and material safety at sites where T&E educators delivered PD collaboratively with science educators. This research supports previous concerns regarding science educators' preparation to adequately teach safer engineering practices (Buchanan, 2013; Hosni, 2013; Love, 2014, 2015b; Nadelson & Farmer, 2012; Roy, 2013). It also reinforces recommendations from STEM education safety specialists who suggested the most effective way to teach educators about the safer use of engineering tools and materials in science is through collaboration with T&E educators (DeLuca et al., 2014; Love, 2013a, 2013b, 2014, 2015a, 2015b; Roy, 2012, 2013, 2014a, 2014b, 2015).

Recommendations

For Practitioners

As indicated from the review of literature and reinforced by the participants' responses, safer use of engineering tools and materials should be a key component of elementary education instruction to help students develop safer habits at an early age (Love, 2015b). To limit their liability and ensure teachers understand the proper safety precautions associated with teaching engineering practices, school systems and teacher preparation programs should collaborate with T&E educators to provide adequate pre and in-service training opportunities for science educators. Classrooms and laboratories must be properly designed or modified to facilitate safer engineering and science instruction (Roy, 2014a, 2014b; Stephenson et al., 2003). Additionally, school systems have a duty to ensure that safer practices are being demonstrated by their teachers. This should be accomplished through supervision of instruction, helping teachers recognize and analyze safety concerns, and setting goals for designing safer learning environments.

For Researchers

Beyond the pre and postsurveys administered at the PD, no follow-up data was collected to investigate if participants continued to implement safer practices throughout the school year. It is recommended that future research observe the safety practices of science educators teaching engineering concepts, and also investigate the longitudinal influence that PD has on safer instruction. Qualitative observations and interviews would help obtain the detailed data needed to address this concern. Furthermore, a replication study examining the gains of secondary level science educators is warranted since their self-efficacy and expected outcomes regarding safety may differ from elementary level science teachers (Hassan & Tairab, 2012). Further research is also needed to examine if there are identifiable differences among female and male teachers' perceptions regarding safer use of engineering tools and materials.

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Acknowledgements: The author would like to acknowledge Dr. Ken Roy for their professional review and contributions to this article. This research is from the Virginia Initiative for Science Teaching and Achievement (VISTA), a five-year professional development project that was supported by funding from the U.S. Department of Education Investing in Innovation (I3) grant program. Any opinions, findings, conclusions, or recommendations expressed in this article are those of the author and do not necessarily reflect the views of the U.S. Department of Education.

Appendix A

Modified STEBI Instrument Items

Instructions: This survey will be used to examine your beliefs regarding the use of engineering hand tools (ex. hammers, screw drivers, hand saws, glue guns, tin snips, cordless drill, etc.) and materials (dowel rods, popsicle sticks, balsa wood strips, plastics, metals, etc.) to ***safely*** teach engineering concepts within science education.

1. When a student does better than usual in science, it is often because the teacher exerted a little extra effort toward the safer use of tools and materials for engineering activities.
2. I will continually find better ways to teach about the safer use of engineering tools and materials.
3. Even if I try very hard, I will not teach about the safer use of engineering tools and materials as well I will most subjects.
4. When the science grades of students improve, it is often due to their teacher having found a way to incorporate the safe use tools and materials for engineering activities.
5. I know the necessary steps for teaching about safer use of engineering tools and materials.
6. I will not be very effective in monitoring the safe use of engineering tools and materials.
7. If students are underachieving in science, it is most likely due to ineffective integration and instruction about safely using tools and materials for engineering activities.
8. I will generally teach engineering tool and material safety concepts ineffectively.
9. The inadequacy of a student’s science background can be overcome by good teaching, which safely incorporates engineering tools and materials.
10. The low science achievement of some students cannot generally be blamed on their teachers for not allowing them to safely use engineering tools and materials for activities.
11. When a low-achieving child progresses in science, it is usually due to extra effort to safely integrate engineering tool and material usage by the teacher.
12. I understand engineering tool and materials well enough to be effective in teaching how to safely use them.
13. Increased effort in safely using tools and materials to teach engineering concepts produces little change in some students’ science achievement.
14. The teacher is generally responsible for the achievement of students in science through the integration of safe use of engineering tools and materials.
15. Students’ achievement in science is directly related to their teacher’s effectiveness in teaching about safely using engineering tools and materials.
16. If parents comment that their child is showing more interest in science at school, it is probably due to the performance of their child’s instructor regarding the safe use of engineering tools and materials.
17. I will find it difficult to explain to students how to safely use engineering tools and materials.
18. I will typically be able to answer students’ questions about the safety of engineering tools and materials.
19. I wonder if I will have the necessary skills to teach how to safely use engineering tools and materials in science.
20. Given a choice, I will not invite the principal to evaluate my teaching regarding the safe use of engineering tools and materials in science.
21. When a student has difficulty understanding an engineering tool or material safety concept, I will usually be at a loss as to how to help them understand it better.
22. When teaching science, I will usually welcome student questions about the safer use of engineering tools and materials.
23. I do not know what to do to motivate students to learn about safer use of engineering tools and materials.

Supplemental Questions

24. Have you ever taught any courses that required you and/or students to use engineering tools or materials? (Circle one below, if yes please list the names of the course[s])
    No Yes: ___________________________________
25. In high school how many shop, industrial arts, or technology and engineering education courses did you complete? (Technology and engineering education is the current name for what used to be known as “shop” class. Please do not count instructional technology courses such as computer or business education in your answer below).
    0 1 2 3 4 5+

26. Have you received any previous training or professional development on how to safely use engineering tools and materials? (Circle one below, if yes please explain where)
No Yes: ________________________________
27. Have you used any engineering tools or machines prior to this workshop? (ex. at home as a child, home projects as an adult, taught "shop" courses, girl/boy scouts, etc.) If so, briefly explain the types of tools used and the context in which they were used.
28. What did you find useful about this professional development in regards to tool and machine safety? How much did it increase your awareness of laboratory safety? What additional questions/comments/recommendations do you have?

Appendix B

Table 7. STEBI Item Differences from Mean Pre to Postsurvey Scores by Site

	Self-Efficacy			
	*Site 1	Site 2	Site 3	Site 4
Item	Diff.	Diff.	Diff.	Diff.
2	0.15	0.35	**0.42**	0.07
3	0.04	0.08	**0.31**	-0.25
5	1.00	**1.28**	1.06	1.25
6	**0.44**	0.03	0.25	-0.14
8	0.33	0.15	**0.44**	0.00
12	**1.22**	0.75	1.17	0.89
17	**0.44**	0.37	**0.44**	0.25
18	0.59	0.50	**0.64**	0.61
19	**1.33**	0.48	0.72	0.57
20	**0.48**	0.27	0.44	0.11
21	0.37	0.28	**0.56**	0.07
22	0.22	0.15	**0.36**	-0.14
23	**0.70**	0.37	0.69	0.18
Total Diff.	7.33	5.05	**7.50**	3.46
	Expected Outcomes			
1	0.41	0.28	**0.53**	0.18
4	0.33	**0.35**	0.25	0.07
7	**0.22**	0.10	0.03	-0.18
9	0.07	0.03	**0.11**	-0.11
10	-0.22	**0.03**	-0.06	-0.18
11	**0.00**	**0.00**	-0.08	-0.11
13	**0.30**	0.07	-0.22	-0.18
14	-0.04	**0.03**	0.00	-0.36
15	-0.41	**0.05**	-0.06	-0.32
16	0.22	**0.32**	-0.19	-0.18
Total Diff.	0.89	**1.25**	0.31	-1.36

Note. * = T&E educators helped deliver PD at this site; Diff. = differences.