Embedding Safety in Integrative STEM Teaching Methods Courses for Pre-Service Elementary Educators

Tyler S. Love

Abstract

Academic standards in the United States advocate for the integration of science, and technology and engineering (T&E) content and practices within the elementary grades (ITEEA, 2020; NGSS Lead States, 2013). However, elementary educators often receive limited preparation for developing and facilitating safer hands-on science and T&E learning experiences (Love, 2017a), which can contribute to their reluctance to integrate science and T&E instruction. This study addresses the issue by examining changes in elementary pre-service teachers' (PSTs) views toward safety and perceived preparation to safely infuse design-based science and T&E instruction following participation in an integrative science, technology, engineering, and mathematics (STEM) education (Wells & Ernst, 2015) methods course. A cohort of 27 elementary PSTs were split into two class sections. The control group participated in a safety jigsaw lesson the first day of classes, whereas the experiment group participated in a safety warm-up activity at the beginning of every class throughout the 15-week semester. Findings indicate all participants reported significant gains in self-efficacy and expected outcomes toward safety, views about the percentage of time elementary integrative STEM lessons should include hands-on learning experiences, perceived knowledge of integrative STEM safety concepts, and perceived ability to safely teach integrative STEM lessons. Further analyses revealed no significant differences between the two class sections. Results suggest that, in addition to emphasizing and demonstrating required safety protocols before any activity, varying strategies used to embed safety instruction in methods courses can significantly increase elementary PSTs' views toward safety in integrative STEM education.

Keywords: Elementary education, elementary engineering, elementary science, teacher preparation, safety and liability, risk management.

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Introduction

In the elementary grades in the United States (U.S.), the amount of daily instructional time involving science and technology and engineering (T&E) concepts is substantially less than that focused on reading, literacy, and mathematics (Daugherty et al., 2022; Douglas et al., 2016; Love, Bartholomew, & Yauney, 2022; Love, Napoli, & Lee, 2023; Radloff & Capobianco, 2021). For decades researchers have advocated for the benefits of integrating constructivist industrial arts (American Council for Elementary School Industrial Arts, 1983; Bonser & Mossman, 1923; Miller & Boyd, 1970), design and technology (D&T) (Todd, 1997), technology education (Minton & Minton, 1987), children's engineering (Dunn & Larson, 1990; Weaver, 2017), and integrative science, technology, engineering, and mathematics (STEM) education (Cheek, 2021; Daugherty et al., 2022; Swagerty & Hodge, 2019) into elementary curricula. Wells and Ernst (2015) defined integrative STEM education (I-STEM ED) as:

> The application of technological/engineering design based pedagogical approaches to intentionally teach content and practices of science and mathematics education through the content and practices of technology/engineering education. Integrative STEM Education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels. (para. 2)

As Foster and Kirkwood (1997) noted, "The educational literature is replete with discussions of the benefits of having children work with their hands while they learn" (p. 17). Despite over a century of paradigm shifts ranging from industrial arts to I-STEM ED, research and resources developed throughout this time reflect a sustained focus on utilizing making and doing practices in the early grades to educate the whole child by providing tactile opportunities for children to explore and apply literacy, mathematics, creativity, problem-solving, and other concepts.

More recently, the *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013) increased calls for instructional time dedicated to engineering practices in the elementary grades (Love, 2017a). However, despite the learning benefits of engineering design experiences at the elementary level, Roy (2011) cautioned there was often limited attention to safety in elementary STEM activities and many elementary educators lacked adequate training to deliver safer hands-on STEM instruction. Recognizing these concerns and the importance of safety to integrate hands-on science and engineering practices in the elementary grades, Flinn Scientific in collaboration with the Council of State Science Supervisors (CSSS), published a guide with recommendations for safer tool use (e.g., hand and power tools) in elementary STEM education settings (Flinn Scientific, Inc, 2021). Moreover, the *Standards for Technological and Engineering Literacy* (STEL) (ITEEA, 2020) emphasize the importance of integrating design-based making and doing practices at the elementary level, but the STEL were found to include a greater focus on safety in comparison to the NGSS (Love et al., 2020) (e.g., STEL standards 1H and 2B). In addition to science and T&E standards documents calling for greater integrative efforts, the growth of collaborative learning environments within elementary schools (e.g., makerspaces) has increased interdisciplinary learning opportunities while also heightening safety concerns (Love, 2022b; Love & Roy, 2022; Swagerty & Hodge, 2019). One reason for these concerns is the limited safety preparation that elementary educators often receive related to the amalgam of tools, materials, and processes that are part and parcel of design-based integrative STEM lessons (Love, 2017a; 2022b; Roy, 2011).

Literature Review

Bonser and Mossman (1923) were early advocates for hands-on technological learning experiences integrated within elementary curricula. They also recognized such learning experiences could pose unique safety issues which required careful attention from instructors, "Habits and attitudes of 'safety first' should be developed in all children" (Bonser & Mossman, 1923, p. 460). Later resources such as those published by The American Council for Elementary School Industrial Arts (1983) maintained a focus on safety, suggesting safety was critical for living in a technological society. Moreover, the Council believed elementary students should gain safety knowledge, learn skills to select and appropriately use technologies and materials that are used to create, develop safer psychomotor skills, and enhance their attitude about safety (consisting of concern, alert, self-control, attentiveness, and responsibility). DeLuca et al. (2014) reiterated the importance of developing students' safety knowledge and skills in the affective, cognitive, and psychomotor domains. Furthermore, the STEL maintained safety should be a key focus as students develop interdisciplinary design and problem-solving skills, "Using tools safely and learning how to manipulate materials appropriately is an authentic practice of scientists, technologists, and engineers" (ITEEA, 2020, p. 77).

In addition to T&E concepts being integrated into elementary curricula in the U.S., numerous countries have included similar learning experiences in their primary curricula for many years. Todd (1995) gave a detailed description of the inclusion of D&T in the United Kingdom (U.K.). D&T remains a required component of the U.K. national primary curriculum at Key Stage 1 (ages 5-7) and Key Stage 2 (ages 8-11), and the Design and Technology Association (DATA) provides numerous resources and trainings to help facilitate safer making and doing practices in the primary grades (Love, 2019). In Sweden, the crafts core content from the Curriculum for the Compulsory School also includes a focus on safer making and doing as students enhance their understanding of, "Hand tools and instruments, what they are called and how they are used in a safe and appropriate way" (Swedish National Agency for Education, 2018, p. 255). Similarly, the Design and Technologies Processes and Production Skills content area of the Australian D&T curriculum includes an emphasis on safety as students progress through the primary grades (e.g., "Select and use materials, components, tools, equipment and techniques and use safe work practices to make designed solutions (ACTDEP016)") (ACARA, 2018).

In the U.S., Weaver (2017) demonstrated how elementary educators could help students learn valuable safety skills while using hand tools to develop solutions to design challenges aligned with the *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007). More recent literature has highlighted the importance of safety during hands-on makerspace (Swagerty & Hodge, 2019) and I-STEM ED (Cheek et al., 2021; Daugherty et al., 2022) learning opportunities in the elementary grades. As Cheek et al. (2021) described, integrative STEM learning opportunities, like those advocated for by the STEL, are important for helping students develop 21st century skills. Despite the numerous learning benefits from design-based I-STEM ED experiences described in the literature, there were also continual concerns raised about safety and elementary educators' preparation to integrate design and T&E concepts in depth. Additionally, some studies and resources expressed reservations about elementary educators selecting and supervising developmentally appropriate tools and activities for young students. However, the literature on this topic acknowledged that safety is a valuable skill to develop in young children, and the safety of elementary students and the instructor should be a top priority (American Council for Elementary School Industrial Arts, 1983; Bonser & Mossman, 1923; Dunn & Larson, 1990; Miller & Boyd, 1970; Minton & Minton, 1987; Roy, 2011; Swagerty & Hodge, 2019; Weaver, 2017).

Safety Research Related to Elementary STEM Education

Zuga's (1997) review of the literature on elementary technology education found only three studies from the 1960s and one from the 1990s focused on safety related topics. These studies primarily investigated elementary students' motor skills when using items such as coping saws, hand drills, hammers, and other tools. With science (NGSS Lead States, 2013) and T&E (ITEEA, 2020) standards documents placing an increased focus on cross-cutting design-based learning experiences, recent studies have had a broader focus on interdisciplinary safety topics within the context of STEM.

Among the elementary STEM educators who participated in Love and Roy's (2022) national safety study, 29% reported overseeing engineering design challenges in a traditional classroom facility while 71% used a dedicated lab or makerspace facility. Moreover, participants reported receiving STEM education safety training from the following sources: an undergraduate (33%) or graduate (43%) degree program, school district upon initial hiring (33%), and school district or professional association safety refresher/update training within the past five years (57%) (Love & Roy, 2023). Although these statistics are not generalizable to all elementary educators who are integrating design-based STEM activities, the lack of safety training is extremely concerning as comprehensive safety training experiences have been found to reduce the occurrence of accidents in STEM courses by 49% (Love, Roy, & Sirinides, 2023). As researchers have described, safety training for educators teaching potentially hazardous lab activities at any grade level is required under federal and state occupational safety and health standards. (Love & Roy, 2022, pp. 35-36; Love, Roy, & Sirinides, 2023, p. 9). Roy (2011) proposed that better professional practices and legal safety standards suggest safety instruction should be more than a "one-time 'drive-by' training experience" (p. 8). Adequate safety training for educators, followed by appropriate training and supervision of students, must be a top priority for maintaining safer elementary integrative STEM teaching and learning environments (Roy, 2011).

Other studies have also raised concerns about the lack of safety knowledge and training among elementary educators tasked with providing design-based integrative STEM instruction. Following the release of the NGSS, numerous studies examined elementary educators' safety practices during engineering design challenges. Some of these studies specifically focused on differences in teachers' safety views and practices when participating in professional development (PD) that was led by T&E teacher educators compared to science teacher educators (Grubbs et al., 2016; Love, 2017a). Educators who participated in the PD experiences led by T&E teacher educators had a more creative and expansive view of engineering design, and used a broader selection of materials and tools to safely design solutions (Grubbs et al., 2016). Love (2017a) found educators in T&E teacher educator led PD sessions experienced significantly greater gains in their safety self-efficacy and tool/materials safety awareness than educators at the PD sites led by science teacher educators. Additionally, Love (2017b) found female elementary educators participating in design-based I-STEM ED PD experienced significantly greater gains in their safety self-efficacy than male elementary teachers. PD efforts specifically focused on safety training relative to I-STEM ED labs and makerspaces have also been found to significantly increase elementary educators' safety self-efficacy (SE) and expected outcomes (EO) related to safer STEM instruction (Love, 2022b; Love, Roy, et al., 2022). However, there is a limited amount of research on safety related to pre-service I-STEM ED. Cheek et al. (2021) examined elementary PSTs who were engaged in a STEL-aligned tinkering and take-apart challenge. They observed that while the PSTs exhibited a sense of inquisitiveness when determining which hand tools were most appropriate for deconstructing items, some PSTs lacked understanding of and confidence in selecting and using the most appropriate hand tools. These studies shed light on the importance of teaching safety concepts in pre-service teacher education programs and in-service PD opportunities related to elementary I-STEM ED.

Safety Beliefs

Bandura (1997) defined SE as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). Increases in SE have been linked to improved teaching practices (Luft et al., 2011) and greater student achievement (Çikrıkci, 2017). Given the ethical and research challenges associated with observing authentic safety practices in K-12 classroom/laboratory/makerspace settings (Love, Roy, et al. 2022), teachers' SE related to safety has been examined as a measure of their intended safety actions (Love, 2017a, 2017b, 2022b; Love, Roy, et al., 2022). Nykänen et al. (2019) specifically defined safety-related SE as "the degree of confidence in one's ability to perform essential safety-related activities successfully" (p. 331). One SE instrument that has been modified for use in previous studies (Love, 2017a, 2017b) and provided reliable insight about teachers' safety SE is the Science Teaching Efficacy Belief Instrument (STEBI-B) (Enochs & Riggs, 1990). Enochs and Riggs (1990) described how teachers' beliefs can influence their behaviors. In regard to safety, this could mean if an elementary teacher believes their ability to safely facilitate integrative STEM instruction is lacking, they may be hesitant to allow students to engage in I-STEM ED design challenges (or avoid these opportunities all together).

Purpose of the Study

Previous studies have found PD on STEM education safety topics can significantly enhance in-service elementary educators' SE and EO toward safety. Moreover, the literature, better professional safety practices, and legal safety standards suggest reoccurring safety instruction is more effective than a "one-time 'drive-by' training experience" (Roy, 2011, p. 8). However, there have been no studies conducted within STEM education contexts to substantiate these claims. Therefore, the following research questions were developed to examine how differences in the way safety instruction is embedded within integrative STEM methods courses influences elementary PSTs' views about safety.

Research Questions (RQ)

How does embedding safety instruction in elementary integrative STEM methods courses influence PSTs':

RQ1 – Safety self-efficacy?
RQ2 – Expected safety outcomes?
RQ3 – Safety self-efficacy and expected safety outcomes when controlling for how safety instruction is embedded?
RQ4 – Perceived safety knowledge and teaching practices?

RQ5 – Perceived safety knowledge and teaching practices when controlling for how safety instruction is embedded?
RQ6 – Safety self-efficacy and expected safety outcomes when controlling for prior safety experiences?

Method

All participating elementary PSTs were required to take the 15-week integrative STEM methods course that was examined in this study. While these students had one math methods course the previous semester, the integrative STEM methods course was the first and only class they had to complete which focused on methods for teaching design-based integrative lessons involving hands-on laboratory experiences. Some of the main goals of this course were to teach students how to develop integrative 5E lesson plans (Bybee & Landes, 1990), how to align instructional units and assessments with current state and national standards from STEM content areas (e.g., ITEEA, 2020; NGSS Lead States, 2013), model best practices for facilitating safer design-based I-STEM ED instruction, and develop strategies for maintaining a safer learning environment for all students engaged in hands-on I-STEM ED learning experiences. The course had an interdisciplinary focus that modeled methods to integrate science and T&E content and practices within elementary classrooms. Many of the lessons were integrated with standards-aligned literacy and math concepts to help students feel more comfortable with integrating STEM content and practices (Love, Napoli, & Lee, 2023). This was also done to demonstrate how I-STEM ED instruction could be seamlessly infused within elementary curricula that often does not allow much time for content beyond literacy and math (Love, Bartholomew, & Yauney, 2022; Love, Napoli, & Lee, 2023). To model integrative teaching and learning experiences the researcher engaged students in different design-based I-STEM ED lessons each week from the following resources: ITEEA Engineering byDesign (EbD) TEEMS, Project Lead the Way (PLTW) Launch, NASA Beginning Engineering, Science and Technology (BEST), FOSS, TeacherGeek, the ITEEA Elementary STEM Journal's Books to Briefs articles, and the NSTA Science and Children journal's Engineering Encounter articles.

Example Lessons

One lesson that integrated engineering design with literacy was Rosie Revere's Orangutan Dilemma (Love & Griess, 2020). In this challenge students had to design and create an enclosure for the orangutans from the Rosie Revere book, and the enclosure had to involve an alarm system programed through the Crumble microcontroller. In this challenge students had to safely cut Styrofoam and dowel rods, and use hot glue guns to develop their designs. The Styrofoam was cut using a coping saw, and the dowel rods were cut using the multi-cutter from TeacherGeek. The multi-cutter functions like a pair of pruning shearers. Another lesson focused on energy and sustainability, which utilized TeacherGeek materials to design and construct a windmill that illuminated a LED (Love & Strimel, 2013). This lesson followed recommendations from Hummell (2016) to focus on themes found in the book, *The Boy Who Harnessed the Wind*. Students had to safely use a variety of elementary appropriate tools and materials to construct, test, and improve their windmill design (e.g., mini hammers, pliers, screwdrivers, coping saws, multi-cutters, etc.).

Throughout the semester students had to address a number of other potential hazards involved with the various design challenges and investigations. This included chemical hazards during the mixtures lesson from FOSS which investigated conservation of mass (e.g., students had to wear indirectly vented ANSI/ISEA Z87.1 D3 rated goggles to avoid splashing salt water in their eyes). The design challenges also involved physical hazards such as projectiles in the TeacherGeek ping-pong launcher challenge and the FOSS rubber band powered air trolley challenge. This required the use of tools like coping saws, scissors, hot glue guns and others to design solutions out of popsicle sticks and other common low-cost craft materials (students had to wear ANSI/ISEA Z87.1 D3 rated safety glasses with side shields, long hair/jewelry/baggy clothing was required to be secured or removed, heat resistant gloves were utilized when operating the hot glue guns like an elementary student would be expected to do, callout procedures and safety zones prior to launching items were established, etc.). Addressing biological hazards related to animals, outdoor/field experiences, and other sources were discussed during the safety jigsaw and safety warm-up activities described in the next section.

Control and Experiment Group Procedures

Twenty-seven students from the elementary PST cohort at a land-grant institution were divided into two class sections due to the net square footage of the elementary-like classroom where the course was taught on campus, safer occupancy load research findings (Love, 2022a; Love, Roy, & Sirinides, 2023), and NFPA 101 guidelines for occupancy in spaces facilitating lab activities (Love & Roy, 2022). The researcher's program chair randomly assigned students to the class sections prior to the start of the semester. Each section discussed the same safety readings and participated in the same I-STEM ED lab-based lessons. The control group (n = 13) participated in a safety jigsaw activity on the first day of class. Students were split into pairs and each group reviewed two safety articles from a list purposefully selected by the researcher/instructor. These safety articles covered pertinent elementary integrative STEM safety topics, many of which were short pieces published by Dr. Ken Roy in *Science and Children* and recent elementary safety guides published by professional associations and councils (e.g., Flinn Scientific, Inc, 2021). Students documented key facts from the articles in a digital interactive whiteboard and then presented a summary of each article to the class. The instructor used these presentations to provide authentic scenarios, pose thought provoking questions, and foster class discussion. Conversely, the experiment group (n = 14) started class each week with a safety warm-up activity. Students read one assigned article or guide each class. They documented key facts in a digital interactive whiteboard and the instructor used those posts to facilitate class discussions after the warm-up. Students from both cohorts had access to all safety readings and their interactive whiteboard via a learning management system. The cohorts were similar in regard to gender and percentage of students with disabilities.

To adhere with better professional practices and legal safety standards, students were required to sign a safety acknowledgement form and pass all applicable safety tests (e.g., coping saw, hand tool safety, hot glue gun safety) prior to participating in any lab activities. The researcher/instructor had a duty to include all safety precautions associated with the design challenges on the worksheets provided to students, demonstrate safer practices for equipment/materials/procedures prior to all lab activities, and directly supervise students to address any foreseeable safety issues during the lab activities. For example, the instructor demonstrated how to safely use a coping saw and the multi-cutters, and how to safely carry hand tools and materials from the TeacherGeek makerspace cart to their table. Students in both class sections took the pre-survey prior to the first class, and the post-survey during the last class session.

Instrumentation

The STEBI-B (Enochs & Riggs, 1990) was used to collect data about changes in participants' views toward safety after participating in the semester-long elementary integrative STEM methods course. Enochs and Riggs originally developed the STEBI-B to measure two constructs: (1) SE toward teaching elementary science, and (2) EO from PSTs' teaching of elementary science. It consists of 23 (13 SE and 10 EO) items measured on a five-point Likert scale. Enochs and Riggs found the instrument to have strong reliability and validity measures. Bleicher (2004) later reexamined the STEBI-B and confirmed it had strong validity measures.

The STEBI-B instrument has been adapted for numerous studies across STEM disciplines, including safety studies. It was modified and demonstrated strong reliability measures for studies examining changes in educators' safety perceptions after using engineering tools and materials in elementary integrative STEM activities (Love, 2017a, 2017b). The author made modifications to the STEBI-B similar to those described in previous studies (Love, 2017a, 2017b). For example, in this study any mention of "science" was replaced with "STEM", and "safety" was added to each question. The following are examples of a SE and an EO question from the survey respectively: Item 5) I know the steps necessary to teach STEM safety concepts effectively, and Item 9) The inadequacy of a student's STEM safety background can be overcome by good teaching. Supplemental questions were also added at the beginning of the pre-survey and the end of the post-survey to collect additional information about participants' prior experiences with STEM education related safety issues, and their perceived preparation to facilitate safer elementary STEM instruction (e.g., data analyzed in RQ4 and RQ5). Due to the slight modifications made to the STEBI-B items, Crohnbach's alpha tests were conducted for internal reliability. The pre-survey (.785) and post-survey (.820) SE items, as well as the pre-survey (.701) and post-survey (.727) EO items demonstrated strong reliability measures.

Data Analyses

Wilcoxon matched pairs tests were deemed most appropriate (Sheskin, 2011) for examining the differences between two related, nonparametric samples (pre- and post-survey items) in RQ1 (changes in SE), RQ2 (changes in EO), and RQ4 (changes in perceived safety knowledge and teaching practices). Effect sizes for the Wilcoxon matched pairs tests were calculated using the formula presented by Pallant (2020). For RQ3 (changes in SE and EO) and RQ5 (changes in perceived safety knowledge and teaching practices), Mann-Whitney U analyses were used to test for significant differences among two separate, nonparametric samples (control group and experiment group) (Sheskin, 2011). Quade's-test, a non-parametric version of ANCOVA (Lawson, 1983), was deemed most appropriate for RQ6. The Quade's-tests examined if participants' level of prior safety experience (covariate) significantly influenced their SE and EO (dependent variables) according to intervention group (independent variable). The p value for statistical significance was <0.05 for all analyses in this study.

Participants

All participants were undergraduate pre-service elementary education (grades PK-4) majors. The sample was mostly white (78%) and female (96%). Participants reported having limited (22%) to moderate (59%) prior experiences with safety in grades PK-4 STEM lessons. Additionally, the experiment group included more participants (92%) who reported having moderate to extensive prior safety experiences compared to the control group (57%) (Table 1).

Table 1
Participant Demographics

Characteristic	Con. n (%)	Exp. n (%)	Total n (%)
Gender			
Male	1 (7)	0 (0)	1 (4)
Female	13 (93)	13 (100)	26 (96)
Ethnicity			
White	9 (64)	12 (92)	21 (78)
Hispanic	1 (7)	0 (0)	1 (4)
Black	1 (7)	0 (0)	1 (4)
Asian	2 (14)	1 (7)	3 (11)
Two or more ethnic groups	1 (7)	0 (0)	1 (4)
Prior experience with STEM education safety			
Extensive	2 (14)	2 (15)	4 (15)
Moderate	6 (43)	10 (77)	16 (59)
Limited	5 (36)	1 (8)	6 (22)
None	1 (7)	0 (0)	1 (4)

Note: Con. = Control group, n = 14; Exp. = Experiment group, n = 13; Total n = 27

Results

RQ1: Changes in safety SE

Research question one examined the changes in participants' safety SE after participating in the methods course. Wilcoxon matched pairs tests revealed significant gains for each group and the full sample regarding their self-efficacy toward teaching safety (Table 2). There was a strong effect size for all three groups; however, the experiment group reported the largest effect size (r = 0.863).

Table 2
Wilcoxon Matched Pairs Tests for Changes in Safety Self-Efficacy

Group	n	Median	IQR	Z	P-value	r
Control						
Pre	14	50.5	6.5	-3.204	0.001*	0.856
Post	14	61	11.25			
Experiment						
Pre	13	46	10	-3.112	0.002*	0.863
Post	13	62	11.50			
Full Sample						
Pre	27	48	9	-4.363	<0.001*	0.840
Post	27	62	11			

Note. * = statistical significance at the $p < 0.05$ level.

RQ2: Changes in safety EO

The second research question examined changes in participants' EO for safety as a result of their teaching after completing the methods course. Wilcoxon matched pairs tests showed significant gains for each group's EO toward safety (Table 3). There was a moderate effect size for each group, with the control group reporting the largest effect size (r = 0.651).

Table 3

Wilcoxon Matched Pairs Tests for Changes in Expected Outcomes

Group	n	Median	IQR	Z	P-value	r
Control						
Pre	14	36	4.5	-2.436	0.015*	0.651
Post	14	38	6.5			
Experiment						
Pre	13	37	3.5	-2.244	0.025*	0.622
Post	13	42	10.5			
Full Sample						
Pre	27	36	3	-3.297	<0.001*	0.635
Post	27	40	9			

Note. * = statistical significance at the $p < 0.05$ level.

RQ3: Changes in safety SE and EO according to class section

Research question three investigated changes in participants' safety SE and EO according to how safety instruction was embedded within the methods course. Mann-Whitney U tests revealed there was no significant difference between the SE and EO gains of the two class sections (Table 4).

Table 4

Mann-Whitney U Tests for Differences in SE and EO Between Class Sections

Group	n	Median	Mean Rank	U	Z	P-value
SE						
Control	14	8.5	12.36	68.000	-1.118	0.264
Experiment	13	13	15.77			
EO						
Control	14	3.5	13.71	87.000	-0.198	0.843
Experiment	13	3	14.31			

RQ4: Changes in perceived safety knowledge and teaching practices

The fourth research question examined changes in participants' safety views measured by the supplemental survey questions. The three supplemental questions asked: (1) What percentage of an integrative STEM education lesson do you believe should involve hands-on labs or activities?, (2) How would you rate your perceived knowledge about safety related to teaching integrative STEM education lessons for elementary students?, and (3) How would you rate your perceived ability to safely facilitate integrative STEM education instruction for elementary students? Wilcoxon matched pairs tests revealed both class sections experienced significant gains for each supplemental question. Upon closer examination, both sections reported significant gains with a moderate effect size for their views about the percentage of hands-on time, but the experiment group had the largest effect size. For participants' views about their perceived knowledge of safety concepts, each group reported significant gains with strong effect sizes with the experiment group demonstrating the largest effect size. Lastly, in regard to participants' views about their perceived ability to safely teach I-STEM ED concepts, each group as well as the full sample reported significant gains with moderate effect sizes. The control group reported the largest effect size for this supplemental question (Table 5).

Table 5
Wilcoxon Matched Pairs Tests for Changes in Views About Safety

Group	n	Median	IQR	Z	P-value	r
Percentage of Hands-on Time						
Control						
Pre	14	4	2.5	-2.132	0.033*	0.570
Post	14	5	2			
Experiment						
Pre	13	3	3	-2.154	0.031*	0.597
Post	13	5	2.5			
Full Sample						
Pre	27	3	3	-2.994	0.003*	0.576
Post	27	5	3			
Perceived Knowledge of Integrative STEM Safety Concepts						
Control						
Pre	14	1	0	-3.372	<0.001*	0.901
Post	14	4.5	1			
Experiment						
Pre	13	1	1	-3.270	0.001*	0.907
Post	13	5	1			
Full Sample						
Pre	27	1	0	-4.639	<0.001*	0.893
Post	27	5	1			

Group	n	Median	IQR	Z	P-value	r
Perceived Ability to Safely Teach Integrative STEM Concepts						
Control						
Pre	14	3	1	-2.762	0.006*	0.738
Post	14	4	1			
Experiment						
Pre	13	3	0.5	-2.598	0.009*	0.721
Post	13	4	0			
Full Sample						
Pre	27	3	1	-3.758	<0.001*	0.723
Post	27	4	1			

*Note. * = statistical significance at the $p < 0.05$ level.*

RQ5: Changes in perceived safety knowledge and teaching practices according to class section

Research question five investigated differences in participants' responses to supplemental survey questions according to intervention group. Mann-Whitney U analyses indicated no significant difference between gains reported by the two groups regarding percentage of hands-on learning time they believe should occur in I-STEM ED lessons, their perceived knowledge of I-STEM ED safety concepts, and their perceived ability to safely teach I-STEM ED concepts (Table 6).

Table 6

Mann-Whitney U Tests for Differences Among Groups' Safety Views

Group	n	Median	Mean Rank	U	Z	p-value
Percentage of Hands-on Time						
Control	14	0	13.79	88.000	-0.153	0.878
Experiment	13	1	14.23			
Perceived Knowledge of Integrative STEM Safety Concepts						
Control	14	1	14.07	82.000	-0.481	0.630
Experiment	13	1	13.92			
Perceived Ability to Safely Teach Integrative STEM Concepts						
Control	14	3	13.36	90.000	-0.052	0.959
Experiment	13	4	14.69			

RQ6: Changes in safety SE and EO according to prior safety experiences

Following the previous analyses, the researcher wanted to examine if prior safety experiences had a significant influence on participants' safety SE and EO considering the experimental group included a larger percentage of students who reported having moderate to extensive prior experiences with elementary STEM safety. Quade's-tests revealed that prior level of safety experience did not have a significant influence on participants' SE [$F(1, 25) = 1.418$, $p = 0.245$] or EO [$F(1, 25) = .003$, $p = 0.955$] when accounting for class section.

Discussion

There are several limitations with this study. The findings represent the self-reported beliefs of 27 elementary PSTs from one university and may not be generalizable beyond the sample. Although the sample lacked diversity in terms of ethnicity and gender, the sample was reflective of the mean demographics for elementary educators in the state where the study was conducted (Shaw-Amoah, 2022). It is also important to note that the courses were limited to 15 weeks, meeting for a single three-hour class session each week. The instructor possessed expertise in laboratory safety and delivering safety trainings (e.g., Love, 2022b; Love, Roy, et al., 2022). Furthermore, the survey items examined participants' beliefs and perceived views about safety. As Love, Roy, et al. (2022) pointed out, studies examining teachers' safety SE can help predict expected safety behaviors, but additional research is needed to investigate teachers' implementation of safety practices over time within authentic classroom settings.

The findings revealed that both class sections reported significant increases in their safety SE and EO. Embedding safety through a warm-up activity each class (experiment group) had a greater effect ($r=0.863$) on PSTs' SE in comparison to the control group ($r=0.856$). Conversely, the one-day safety jigsaw activity at the beginning of the semester (control group) had a greater effect on PSTs' EO ($r=0.651$) in comparison to the experiment group ($r=0.622$). Furthermore, there were significant increases for both class sections in regard to their views about percentage of I-STEM ED instructional time that should be dedicated to hands-on learning, perceived knowledge of I-STEM ED safety concepts, and perceived ability to safely teach I-STEM ED concepts. The experiment group reported a larger effect size than the control group pertaining to changes in views about percentage of hands-on time and perceived safety knowledge. However, the control group experienced a greater effect than the experiment group regarding their perceived ability to safely teach STEM concepts. The larger effect size for SE gains reported by the experiment group may be related to the continual building of students' safety confidence from week to week during the warm-up activities. The greater effect on safety knowledge reported by the experiment group may also be a result of the reinforcement of safety concepts discussed from week to week. While the experiment group experienced a greater effect size reflecting safety content related items (SE and perceived knowledge of safety), the control group reported a greater effect size reflecting safety practices related items (safety EO from students as a result of their teaching and perceived ability to safely teach I-STEM ED). The control group received approximately 15 minutes more to engage in the hands-on I-STEM ED design challenges each class because they did not have the safety warm-up activity. This time for additional hands-on experiences could have potentially influenced the PSTs' views about safety practices.

Despite the significant changes reported by each group and the full sample, the class sections did not significantly differ in regard to their safety SE gains, EO gains, views about percentage of hands-on time in elementary I-STEM ED, change in perceived safety knowledge, or change in perceived ability to safely teach I-STEM ED concepts. The researcher hypothesized that prior safety experiences would have an influence on the gains between the two groups; however, RQ6 revealed there were no significant differences between the groups when accounting for prior elementary STEM safety experiences. Overall, the results of this study indicate that the safety instruction embedded within each I-STEM ED methods course significantly increased PSTs' views about safety and safer teaching of design-based I-STEM ED lessons. While the literature, better professional safety practices, and legal safety standards all suggest safety instruction should be a reoccurring event (Roy, 2011), this study did not find significant differences in PSTs' views about safety whether safety instruction was delivered one-day in the beginning of the semester versus at the beginning of each class throughout the semester. There is a possibility that these findings may have been influenced by confounding variables that were not accounted for in this study. Those potential confounding variables, which are discussed in the following section, should be considered in future safety studies.

Conclusions and Recommendations

While the findings from this study appear to contradict recommendations that safety instruction should be more than a one-time drive by occurrence (Roy, 2011), there are other confounding variables that need to be carefully considered when interpreting the findings. As Love, Roy, et al. (2022) explained, examining the safety practices of K-12 STEM educators can be very challenging. Educators delivering and supervising I-STEM ED lessons have legal and ethical duties to facilitate safer teaching and learning experiences. Based on the literature, the researcher predicted that PSTs who participated in daily safety warm-up activities would demonstrate greater gains in their views toward safety. However, students in the control group also viewed safety demonstrations and received safety reminders before every lab activity conducted throughout the semester. It is unknown if this influenced the participating PSTs' safety views;

however, it could not be removed due to legal and ethical obligations. The researcher, who was also the instructor of both class sections, acknowledges that they wanted to prepare the PSTs to deliver I-STEM ED instruction in the safest manner possible. They recognized that they had to demonstrate appropriate safety practices for all students, but made a conscious effort in the control group class not to discuss the safety readings from the jigsaw activity beyond the first class session. This study did not investigate if students made connections to those articles when viewing the safety demonstrations prior to each design challenge. The researcher/instructor made sure to provide the same thorough safety demonstrations before each design challenge for both class sections. Further research is needed to investigate the effect of potential confounding variables like those mentioned above.

The researcher cautions I-STEM ED teacher educators and elementary teacher educators in interpreting the findings. While in-depth safety instruction can be effectively embedded using varying strategies as presented in this study, instructors should not eliminate safer practices (e.g., testing, demonstrations, and reminders) that must accompany any lesson posing potential hazards. This could result in an educator being found negligent or reckless, posing serious consequences. Future studies should consider collecting and analyzing midpoint data to more closely examine changes in PSTs' safety views while also accounting for how safety instruction is embedded. Moreover, researchers should also consider utilizing qualitative methods to examine PSTs' digital interactive whiteboard responses for potential differences that emerged from the safety readings.

Ethics approval

This research was approved by the Office for Research Protections at The Pennsylvania State University.

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About the Author

Tyler S. Love (tslove@umes.edu) is a Professor, Coordinator of Undergraduate Technology and Engineering Education, and Director of Graduate Studies in Career and Technology Education for the University of Maryland Eastern Shore at the Baltimore Museum of Industry. https://orcid.org/0000-0002-1161-1443