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Perceptions of Safety in Makerspaces: Examining the Influence of Professional Development

Session III: Research, Laboratories, and New Initiatives

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Abstract

Makerspaces have become increasingly common in P-16 schools, higher education residence halls, libraries, and community centers. Professional associations such as the American Library Association (ALA), the American Society for Engineering Education (ASEE), the International Society of Technology in Education (ISTE), the International Technology and Engineering Educators Association (ITEEA), and the National Science Teachers Association (NSTA) have all highlighted the educational benefits of these spaces. One such benefit is they can provide increased access to hands-on science, technology, engineering, and mathematics (STEM) learning experiences. Despite providing increased access, these spaces pose inherent safety risks that are often overlooked. This has led educators, administrators, and researchers to question, "Who possesses the appropriate safety expertise to oversee these collaborative spaces?"

The purpose of this study was to investigate if there was a significant difference in educators' perceptions related to makerspace safety after participating in a four-hour professional development (PD) experience. The PD was delivered by a T&E education safety specialist. This study utilized a concurrent quasi-mixed design (Teddlie & Tashakkori, 2006), to investigate the changes in safety perceptions of 18 K-12 educators' (4 secondary T&E, 2 secondary science, 5 elementary, 2 librarians, 2 secondary art, 3 secondary computer science) from approximately 14 school districts in a mid-Atlantic state. Quantitative pre and post-survey ratings derived from the modified Science Teaching Efficacy Belief Instrument, Form A (STEBI-A) were mixed with qualitative content analyses from open-ended survey questions and accident report forms. The survey data was also analyzed for differences according to the participants' gender and certification area. The findings suggested that the PD experience had a significant influence on participants' safety perceptions, however there were no significant differences among gender or certification area. Almost three-quarters (72%) of the participants indicated the PD positively influenced their knowledge on a variety of safety topics.

The findings also suggested that PD delivered by someone with T&E education safety expertise can have a significant influence on educators' perceptions regarding safety concerns in makerspaces. The conclusions drawn from the data analyses provide implications for conducting future studies on a larger scale, informing similar PD experiences, and increasing collaborative efforts for safer makerspace learning experiences.

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Introduction

When examining makerspaces, it is important to first define what exactly constitutes a makerspace? A common misconception is that makerspaces are defined by the high-tech equipment and materials that are found within the space. However, what makes makerspaces unique are the opportunities they provide for communities of innovators and entrepreneurs to collaborate and apply their science, technology, engineering, and mathematics (STEM) skills, resulting in solutions to authentic problems. Makerspaces can be defined as:

> A space where kids have the opportunity to make – a place where some tools, materials, and enough expertise can get them started. These places, called makerspaces, share some aspects of the shop class, home economics class, the art studio, and science labs. In effect, a makerspace is a physical mash-up of different places that allows makers and projects to integrate these different kinds of skills. (Honey & Kanter, 2013, p. 9)

Makerspaces were born out of the maker movement, a grassroots movement influenced by the ideals of John Dewey. The launch of the maker movement is often associated with the release of the hobbyist Make Magazine in 2005. The maker movement continued to grow with the first Maker Faire hosted in 2006. What originally started as an effort to encourage kids to tinker, design, and create, has found its way into formal school and library settings to encourage STEM and creativity (Roy & Love, 2017). Makerspaces, the innovative spaces that support maker learning, have also become increasingly popular. Hynes and Hynes (2018) described makerspaces as an updated version of the industrial arts facilities of the past, "The wood shop of the past is now seeing new life in makerspaces that cut across various media (e.g., sewing, metalworking, woodworking, electronics, etc.) with state-of-the-art tools and resources" (p. 868).

Although makerspaces have arguably helped to reattract people to some of the foundational concepts that have long been associated with the industrial and design roots of technology and engineering (T&E) education, they have done so with little discussion around one critical topic – safety. It is not uncommon to now find makerspaces in school and community libraries, higher education institutions, university residence halls, elementary schools, and secondary schools. However, these spaces are often developed and operated without adequate safety controls, standard operating procedures, employee training, and supervision. Given T&E education's long history with safely using hazardous items to design and create, which relates to many of the arising safety concerns seen in modern makerspaces, T&E educators should be involved with all aspects of makerspaces in school settings (Love & Roy, 2018b). Their training and experience in this area could help mitigate some of the safety concerns raised in the literature.

Literature Review

Safety in Makerspaces and STEM Education

Makerspaces are commonly found in K-12 schools, higher education institutions, and libraries. In 2016 there were approximately 1,400 active makerspaces around the world, 14 times more than in 2006 (Lou & Peek, 2016). Most of the research about makerspaces in these areas has remained siloed, however there is a limited amount of literature examining safety issues in makerspaces across these settings.

Makerspaces in K-12. As schools receive funding to start a makerspace they often have trouble finding a suitable space to house their makerspace. Some districts have created maker carts, or placed a makerspace in their library, cafeteria, or even converted standard classrooms into a makerspace. An issue with this approach is that these areas usually do not have the proper engineering controls required for the items and activities hosted in a makerspace (Love & Roy, 2018b; Roy & Love, 2017). Renovations to these areas can be costly and are often bypassed at the expense of student and faculty safety. There are numerous professional associations and organizations that provide resources for makerspaces. Unfortunately, safety is very rarely a focus of those resources. The International Technology and Engineering Educators Association (ITEEA) and the National Science Teachers Association (NSTA) have led the way in terms of offering safety resources for makerspaces and STEM labs. This may be a result of the integrative nature of the Standards for Technological Literacy (STL) (ITEA/ITEEA, 2000/2002/2007), and the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) mandating the teaching of engineering content and practices, increasing the focus on delivering crosscutting concepts:

> 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. 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)

To address these concerns NSTA (2018) has a safety website that includes links to safety items and a safety blog discussing the latest STEM education safety issues. ITEEA has published safety spotlight articles since 2016 and also has a safety website with resources on various makerspace topics (ITEEA, 2018). Both associations sell a number of safety guides, but to date there is only one book published on makerspaces that focuses exclusively on the safety considerations from a collaborative STEM perspective (Roy & Love, 2017).

Makerspaces in higher education. Makerspaces can be found in various locations across college campuses. Developing a safety culture through appropriate training, access, and supervision are all critical considerations for operating makerspaces in this setting (Klein, Wilczynski, & Campbell, 2016). Makerspaces have been found to be very beneficial in higher education settings due to the opportunities they provide for community learning. This is important during a time when young adults are introduced to a new setting and looking to develop new friendships with people who have similar interests. Higher education institutions have created makerspaces in buildings where their traditional science and engineering labs are located so that students can continue their innovative thoughts beyond class time. These makerspaces usually follow safety policies set forth by their health and environmental safety or risk management offices. They are often overseen by a trained lab manager or graduate assistant. Students are required to sign a safety contract and complete training courses with assessments prior to working in the makerspace. Tufts University serves as an excellent example of a higher education makerspace with these types of safety policies (Tufts University, 2018).

Another setting where makerspaces have been found to be beneficial for their community collaboration aspect is in residence halls. Carnegie Mellon University and Virginia Tech both provide makerspaces for students to work on class projects, participate in scheduled workshops, or collaborate with other students living in their building. These areas are only open when a trained graduate student is supervising the space. At Virginia Tech this type of makerspace is located in Lee Hall, which houses both male and female students majoring in STEM fields (Roy

& Love, 2017). This provides increased access for both male and female students since makerspaces have not been found to be very gender inclusive (Chachra, 2015).

Higher education makerspaces are most often found in or adjacent to their library with the goal of providing a space that is accessible to students across all disciplines (Hynes & Hynes, 2018). While this provides an easy access point to attract a diverse group of makers, it also raises some concerns about the engineering controls and training required for the persons overseeing these library makerspaces.

Makerspaces in libraries. Makerspaces are most often found in libraries due to the ability to provide access to many individuals there. In K-12 and higher education settings, libraries provide a space where a dedicated person who usually does not have teaching responsibilities can assist students with maker projects throughout the day. There are vast examples of makerspaces found in K-12, higher education, and community libraries. Engineering controls and safety training are major issues in libraries because these facilities were not originally designed to host hazardous activities, and librarians usually do not receive safety training in their preparation (Love & Roy, 2018b). The American Library Association (ALA) has supported makerspaces as evidenced in their journals and online resources. Their online store currently offers a very basic makerspace safety poster (ALA, 2018) and one book discussing legal issues associated with makerspaces in libraries (Minow, Lipinski, McCord, 2016). Although these resources acknowledge that safety is a concern in library makerspaces, they lack the depth of information that is needed to safely design and operate a makerspace, something that is provided by NSTA, ITEEA, and Roy and Love (2017).

There are a limited number of libraries and librarians who have made safety a priority through conducting research and developing excellent safety resources. McMenemy (2014) investigated acceptable use policies among 20 libraries in the United Kingdom. He concluded that while emphasis on liability is important, it is equally important to design policies that are consistent, understandable, and promote services in a positive way. Morefield-Lang (2015) examined the makerspace user agreements from 24 public libraries across the United States. Her study found that safety was expressed in the user agreements of only 17 libraries, of which 16 included a liability statement. Given the hazardous nature of items found in makerspaces, the fact that only 17 libraries mentioned safety or liability in their user agreements identifies a lapse in the emphasis on safety in these areas. Examples of two public libraries that have made makerspace safety a focal point by providing waivers, online safety training videos and tests, and tutorials are Johnson County Library (2018) in Kansas and Fayetteville Free Library (2018) in New York. These libraries serve as models for the type of engineering controls, standard operating procedures, and policies that should be a part of any library makerspace.

Librarians and scientists have also conducted numerous studies highlighting the need for appropriate ventilation when using 3D printers due to high ultrafine particle (UFP) emission levels (Bharti & Singh, 2017). This has resulted in developing policies with university Environmental Health and Safety offices (University of Florida, 2016). Research and policies like these can be beneficial to makerspaces in all settings.

Previous makerspace and STEM education safety studies. There is a limited amount of research examining safety topics related to makerspaces, however science and T&E education have published studies examining STEM safety issues that are applicable to makerspaces. Even within the context of K-12 science and T&E education, the amount of safety research conducted within the past two decades is scarce. Plohocki (1998) found that specific pre and in-service trainings did not have a significant influence on science teacher's safety content knowledge.

Another STEM education safety study by Stephenson, West, Westerlund, and Nelson (2003) discovered that one third of science teachers did not have a written safety policy and did not receive adequate safety training. Additionally, this study established that accidents increased at a statistically significant rate as the number of students in a lab class exceeded 24 per one instructor. (**It should be noted that this occupancy recommendation does not override the fire code requirements [NFPA, 2018] for square footage per student in areas where hazardous lab activities are being conducted*). This study has been cited frequently by NSTA (2015) and ITEEA (West, 2016) regarding recommendations for overcrowded STEM labs and makerspaces.

The most recent studies examined STEM education safety in relation to NGSS's engineering practices and provided more collaborative findings. These studies examined elementary educators' perceptions regarding the use of potentially hazardous hand tools and materials to teach design-based science and engineering lessons. Educators expressed reservations about using tools and materials in their classroom, and also had difficulty imagining ways in which they could be safely incorporated to solve engineering design problems (Grubbs, Love, Long, & Kittrell, 2016). Despite these concerns it was discovered that professional development (PD) efforts were influential in increasing teachers' safety self-efficacy. Specifically, STEM PD delivered by T&E teacher educators had a statistically significant influence on educators' tool and materials safety self-efficacy when compared to the same PD delivered by science teacher educators (Love, 2017a). This PD experience also revealed that participating female teachers reported significantly greater gains than male participants (Love, 2017b). Studies such as these demonstrate the influence that PD can have on educators' safety perceptions, consequently leading to safer instructional practices (Love, 2017a; Luft et al., 2011).

Self-Efficacy and Safer Instruction

Observations of safety practices can be time consuming and difficult to capture true habits when a teacher knows they are being observed. A more feasible approach for investigating safety while addressing the aforementioned issues is examining teachers' self-efficacy. Rooted in the work of Bandura (1997), self-efficacy is defined as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). Riggs and Enochs (1990) described how beliefs can influence behaviors, "An elementary teacher judges his/her ability to be lacking in science teaching (belief) and consequently develops a dislike for science teaching (attitude). The result is a teacher who avoids teaching science if at all possible (behavior)" (p. 625–626). This connection between teacher beliefs and behaviors is a key aspect of the Science Teaching Efficacy Belief Instrument, Form A (STEBI-A) developed by Riggs and Enochs (1990).

Teacher efficacy is "one of the key motivation beliefs influencing teachers' professional behaviors and student learning" (Klassen, Tze, Betts, & Gordon, 2011, p. 21). Studies have also linked teacher self-efficacy to instructional quality (Holzberger, Philipp, & Kunter, 2013), and educators with higher self-efficacy have been found to have higher expectations for themselves and their students (Shidler, 2009). In regards to enhancing teacher self-efficacy, PD experiences have shown to be beneficial. Specifically, single PD workshops have been found to positively influence teacher efficacy beliefs as well as student achievement (Fancera & Bliss, 2011; Moolenaar, Sleegers, & Daly, 2012). Therefore, it could be expected that gains in a teacher's makerspace safety perceptions resulting from a single PD workshop would have a positive influence on safety instruction and learning.

Research Questions and Sub-Questions
This study was guided by the following research questions examining participants' experiences and perceptions regarding safety in makerspaces:

RQ1: What is the extent of educators' prior experiences and training related to safety in makerspaces?
RQ2: How did the PD experience influence educators' safety perceptions related to makerspaces?
- **RQ2-SQ1:** To what extent did educators' perceptions change among the overall group?
- **RQ2-SQ2:** To what extent did educators' perceptions differ among male and female participants?
- **RQ2-SQ3:** To what extent did educators' perceptions differ among T&E educators and educators from other content areas?

RQ3: To what extent did the PD experience influence participants' overall awareness of safety issues related to makerspaces?

Methodology and Procedures

A concurrent quasi-mixed design (Teddlie & Tashakkori, 2006), with mixing of quantitative and qualitative data occurring at the experiential and inferential stages, was used to answer the research questions and sub-questions. The author created and delivered the four-hour PD based on important safety topics highlighted by Roy and Love (2017). The PD was comprised of the following presentations: Introduction to makerspaces; federal and state safety standards, liability, and risk management strategies; makerspace hazards (biological, chemical, physical); better professional practices; examples of existing makerspaces and design considerations; and locating safety resources. A pre-survey was administered via paper at the beginning of the PD experience following a brief discussion defining makerspaces and the types of items that could be found in these collaborative spaces. This was intentionally done so that participants with varying background knowledge about makerspaces could better understand the survey questions and provide more accurate responses. Participants were randomly assigned a number to help the researcher link the accident report form, pre-survey, and post-survey during analyses. Pre-surveys were collected immediately after completion so participants could not look at the questions during the PD. After the four-hour PD experience, participants were provided with the post-survey to measure changes in their perceptions of safety.

Following the portions of the PD covering liability and better professional practices, the accident scenario from Love and Roy (2018a) was presented to participants. They were instructed to use their state T&E education association's recommended accident report form to complete the questions as if that scenario occurred in their makerspace.

After all data was collected it was analyzed, beginning with the pre and post-survey demographic questions. They were examined using descriptive statistics, and the supplemental open-ended questions were categorized to allow for quantitative analyses. Using the STEBI-A scoring guide, the appropriate items were reverse scored in SPSS and differences between the post and pre-survey ratings were calculated to conduct further statistical tests as described in the findings section. Similar to the methodology implemented by Stephenson et al. (2003), a content analysis (Vaismoradi, Turunen, & Bondas, 2013) allowed for the accident report form responses to also be categorized. This allowed the researcher to quantitatively examine if there was a relationship between the various participant characteristics reported in the pre-survey and the accident form responses.

Instrumentation

The following quantitative and qualitative items helped to collect data addressing the research questions and sub-questions. Presented below are descriptions of the instruments, development procedures, and methods used to establish reliability.

Survey

Developing the survey. The STEBI-A (Riggs & Enochs, 1990) was used to collect data about participants' change in safety perceptions after attending the PD experience. This instrument was originally developed to measure the self-efficacy and expected outcomes of elementary educators teaching science. Riggs and Enochs found the instrument to have strong reliability and validity measures. It consists of 25 items measured on a five point Likert scale (13 items examining teachers' self-efficacy, and 12 investigating their expected outcomes).

This instrument has been adapted for numerous studies across STEM disciplines, including research in T&E education. Specifically, it was modified and demonstrated strong reliability measures in previous studies examining safety perceptions of STEM educators who participated in a PD experience (Love, 2017a; Love 2017b). The STEBI-A survey instrument that Love (2017a) modified for examining safety practices was found to have strong reliability measures was deemed the most viable instrument for this study. Love's (2017a) instrument was slightly adapted for this study by changing any mention of "engineering tools and materials safety" to "makerspace safety." The following are examples of two questions from the survey: Item 5) I know the necessary steps to teach makerspace safety concepts effectively, Item 12) I understand safety concepts well enough to be effective in teaching in a makerspace. Additionally, supplemental questions were added at the beginning of the pre-survey and the end of the post-survey to collect the depth of data needed to address the research questions.

Reliability and validity measures. Due to the slight modifications for this study, the survey items were tested for reliability using Crohnbach's alpha. The pre-survey (.818) and post-survey (.792) items demonstrated strong and acceptable reliability measures respectively. Furthermore, the pre-survey (.901) and post-survey (.810) self-efficacy items, as well as the pre-survey (.864) and post-survey (.830) outcome expectancy items exhibited strong reliability measures. Face validity of the instrument items was established among a panel consisting of two national makerspace safety specialists, and a district STEM supervisor. Panel members reviewed the language of the instrument items to ensure they were consistent with what was asked in the original STEBI-A and accurately examined topics related to makerspace safety.

Accident Report Form

To investigate participants' application of the liability and safety information presented during the PD, they were asked to complete the accident report form recommended by their state T&E education association. This form consisted of open-ended questions asking about the description of the incident, location of the instructor during the incident, tools/equipment/materials involved, unsafe practices that may have contributed to the incident, and suggestions for preventing a similar incident in the future. The findings presented in the next section were derived from data collected by the aforementioned instruments.

Participants

Participation in the PD was advertised to all librarians, STEM supervisors, science, T&E, math, computer science, and elementary educators within a consortium of public schools in a mid-Atlantic state. Participation was voluntary and teachers could earn continuing education credits from their state department of education for attending. There were 18 participants representing 14 different public school districts within the consortium. The four-hour PD session took place in the morning during the summer, and grant funding obtained by the consortium provided all attendees with a copy of *Safer Makerspaces, Fab Labs, and STEM Labs: A Collaborative Guide!* (Roy & Love, 2017) to keep for their school.

Survey participants were primarily Caucasian (100%) females (72%) with a mean age of 44, and the average years of teaching experience among the group was 16. The most common certification areas and teaching assignments reported by participants were elementary education and T&E education (Table 1).

Table 1

Participant Demographics

Characteristic	n (%)
Gender	
Male	5 (28)
Female	13 (72)
Ethnicity	
White	18 (100)
Teaching Experience	
Less than 5 years	2 (11)
5-15 years	7 (39)
More than 15 years	9 (50)
Certification Area (Grade Level)	
Art (PK-12)	2 (11)
Biology (7-12)	3 (17)
Elementary (PK-4)	5 (28)
Library Science (PK-12)	2 (11)
T&E (PK-12)	5 (28)
No Certification	1 (5)
Current Teaching Assignment (Grade Level)	
Art (K-6)	2 (11)
Computer Science (K-5)	3 (17)
Elementary (K-5)	5 (28)
Librarian (6-8)	2 (11)
General Science (6-8)	2 (11)
T&E (6-12)	4 (22)

Note. T&E = Technology and Engineering education.

Findings

Prior Safety Experiences

Prior safety experiences were reported via supplementary questions on the pre-survey. Descriptive statistics were used to analyze these experiences. More than half (61%) of the participants reported having experience teaching a formal K-12 course that required using tools or equipment, but none of the participants had received any safety training or PD within the past three years (Table 2).

Table 2

Tool/Equipment Experiences and Training

	Taught a formal K-12 course using tools/equipment n (%)	Received safety training/PD in past three years n (%)
Yes	11(61)	0 (0)
No	7 (39)	18 (100)

Supplemental pre-survey questions investing prior experiences with makerspaces and tools/equipment were also included in the pre-survey. Eleven participants (61%) did not currently have a makerspace in their school but were interested in developing one. Among those who indicated they had a makerspace in their school, four (22%) were involved in the designing/planning of the makerspace, and five (28%) were tasked with overseeing or managing the makerspace. Further analyses revealed that none of the participants involved in the designing/planning were currently teaching T&E education courses, and only one of those participants possessed T&E education certification. Additionally, none of the participants in charge of overseeing or managing the makerspace were currently teaching T&E education courses, and only one of those participants had T&E education certification. Educators currently teaching computer science (40%) and art (20%), as well as librarians (40%) reported overseeing or managing their school's makerspace (Table 3).

Table 3

Experiences with Makerspaces

	Makerspace in their school n (%)	Helped design or plan their school's makerspace n (%)	Oversee or manage their school's makerspace n (%)	Taught lessons in a makerspace using tools/equipment n (%)
Yes	7 (39)	4 (22)	5 (28)	8 (44)
No	11 (61)	3 (17)	2 (11)	10 (56)
N/A	0 (0)	11 (61)	11 (61)	0 (0)

Another supplemental question on the pre-survey asked participants to share the extent of their prior experiences with tools and equipment. Following the criteria and methodology used to categorize participants' responses to a similar question in a previous safety study (Love, 2017), these experiences were coded into four categories: None, Limited (e.g., use of basic hand tools at home for arts and crafts), Moderate (e.g., use of power and hand tools for home or student projects), and Extensive (e.g., use of advanced power tools and large equipment for manufacturing/construction projects). Fourteen participants (78%) had prior experience with tools and equipment, seven (39%) of whom reported extensive experiences (Table 4).

Table 4

Extent of Prior Experiences with Tools/Equipment

Experience Level	n (%)
None	4 (22)
Limited	3 (17)
Moderate	4 (22)
Extensive	7 (39)

Safety Perceptions

The modified STEBI-A questions were utilized to examine changes from the pre to post-survey regarding self-efficacy and expected outcomes. These data were analyzed to examine differences according to three different variables.

Overall group. To answer RQ2-SQ1, the differences among all participants' pre and post survey responses were examined according to self-efficacy and expected outcome items. It was determined that a Wilcoxon matched pairs test was best suited for analyzing two related samples (pre and post survey items) with ordinal data from a non-parametric sample (Sheskin, 2011). The analysis revealed the p-values for both the self-efficacy (.001) and expected outcome (.005) responses were less than the alpha value of 0.05 (Table 5). This indicated that the PD had a significant influence on the makerspace safety self-efficacy and expected outcomes of the overall group.

Table 5

Wilcoxon Matched Pairs Tests for Differences Among Pre and Post Survey Items

Items	n	Median	IQR	Test Stat.	*p*
Self-Efficacy					
Pre-test	18	47.0	14	-3.436	.001
Post-test	18	51.0	7		
Expected Outcomes					
Pre-test	18	42.0	12	-2.820	.005
Post-test	18	45.5	8		

Differences among males and females. RQ2-S2 examined the differences among male and female participants' perceptions of makerspace safety. To answer this research question, a Mann-Whitney U test was determined to be best suited for analyzing two independent samples (male and female) with ordinal data from a non-parametric sample (Sheskin, 2011). The analyses found that the p-values for both the self-efficacy (.277) and expected outcome (.881) responses were greater than the alpha value of 0.05 (Table 6). Therefore, it was determined that there was not a significant difference among the safety perceptions of male and female participants.

Table 6

Mann-Whitney U Tests for Differences Among Male and Female Participants

Items	n	Median	Mean Rank	U	Z	*p*
Self-Efficacy						
Males	5	4	7.30	21.5	-1.088	.277
Females	13	5	10.35			
Expected Outcomes						
Males	5	1	9.80	31.0	-.149	.881
Females	13	2	9.38			

Differences among T&E educators and other educators. To answer RQ2-SQ3, Mann-Whitney U tests were again utilized. Survey responses were analyzed and it was discovered that those who possessed T&E certification had taught T&E courses at some point during their career. Therefore, certification was used to identify T&E educators in this study. The tests found that the p-values for both the self-efficacy (.166) and expected outcome (.654) responses were greater than the alpha value of 0.05 (Table 7). From this, it could be concluded that there was not a significant difference among the safety perceptions of T&E educators and other participants.

Table 7

Mann-Whitney U Tests for Differences Among T&E and Other Educators

Items	n	Median	Mean Rank	U	Z	*p*
Self-Efficacy						
T&E	5	4	6.70	18.5	-1.384	.166
Others	13	6	10.58			
Expected Outcomes						
T&E	5	1	8.60	28.0	-.448	.654
Others	13	3	9.85			

Note. T&E = Technology and Engineering educators.

Overall Safety Awareness

Accident report forms. A content analysis (Vaismoradi et al., 2013) of the accident report forms was used to analyze and categorize participants' responses. This analysis revealed that 14 of the 18 participants (78%) provided written responses that could be interpreted as instructor negligence and contributing to the accident scenario provided. Table 8 provides examples of some participant responses.

Table 8

Examples of Participants' Accident Report Form Responses

Participant	Q1	Q2
	Did not indicate negligence	
Teacher 1	"The student failed to secure the material properly."	"Review proper activity procedures."
	Indicated negligence	
Teacher 2	"On the other side of the room working with other students."	"Lack of safety signs and safety zone. Instructor proximity."
Teacher 3	"Teacher was across the room supervising the student."	"Review safety prior to the activity."
Teacher 4	"Across the room. Instructor not present at the activity during operation."	"Instructor should be located at the activity to oversee all usage. Safety zones should be around the activity area."

Note: Q1 = What was the location of the instructor when the accident occurred?; Q2 = What unsafe practices, if any, contributed to the accident? What are your suggestions for preventing a similar incident?

Supplemental survey question. To answer RQ3, the supplemental question at the end of the post-survey was analyzed. This was an open-ended question asking participants if they believed the PD experience influenced their awareness of makerspace safety topics, and if so, what topics and to what extent. These responses were qualitatively coded into three categories following the same procedures and coding scheme utilized by Love (2017a): 1) no, 2) some, and 3) substantial increase. One participant (6%) reported no increase, seven attendees (39%) indicated some increase, and six participants (33%) reported a substantial increase in their safety knowledge. Four participants (22%) did not provide any comments (Table 9).

Seven participants (39%) indicated the PD informed their knowledge in regards to planning a makerspace or reconsidering the safety features/design of their current lab/makerspace. The PD also raised concerns regarding safer instruction. One participant who was a computer science teacher indicated reservations toward utilizing hazardous items, "I am actually less inclined to add the power equipment to my high school classes now. A lot more consideration and discussion will need to come first."

Table 9

Examples of Participants' Safety Awareness Responses

Category	Example of Participant Responses
No increase	"I really wish we had more time to cover lab design considerations."
Some increase	"The information was very useful and relevant, easy to implement in makerspaces and labs."

(continued)

Table 9 Continued

Category	Example of Participant Responses
Some increase	"I especially found the use of symbols for students with disabilities helpful. More strategies of how to include them would be helpful."
Substantial increase	"I found it to be especially useful. I have not had information or a refresher on lab safety since my undergraduate days which was 27 years ago!"
Substantial increase	"This should have been an all-day course. So many of the topics related to makerspaces and STEM were valuable to me."

Discussion and Conclusions

As with any study, there were a number of limitations that existed and must be acknowledged. This study was conducted in one school consortium within a mid-Atlantic state. Results cannot be generalized beyond the participants in this study. Based on the demographics it is apparent the sample in this study ethnic lacked diversity. However, the random sample of educators who volunteered to partake in the PD were from a mix of rural, suburban, and urban school districts. Conducting the study specifically in an urban school system or on a larger scale could have attracted more diversity and offered valuable insight about safety perceptions. Moreover, the PD was limited to four hours, and as indicated in the supplemental post-survey question, some participants wished the PD was a whole day event to cover more topics. More time to cover these topics could have a greater influence on participants' safety perceptions. The perceptions and demographic data relied on participants to self-report. Being able to observe instructors' makerspace or safety practices as opposed to analyzing self-reported data could provide deeper insight.

As the analyses from the survey suggest, the PD experience significantly increased the safety self-efficacy and expected outcomes among the entire group. However, one interesting finding is that there was not a significant difference in gains when examined according to gender or certification area. The literature would lead one to expect to find an identifiable difference according to gender (Love, 2017b) and expertise in T&E education (Love, 2017a). Furthermore, the significant increases in safety perceptions among the group are interesting given the number of participants who reported teaching a formal K-12 course using tools or equipment (61%), taught lessons in a makerspace using tools or equipment (44%), and had moderate to extensive experience using tools or equipment at home (61%). From these prior experiences using and teaching about the use of hazardous items, it would be expected that the PD experience would not have been as influential. One plausible explanation for the significant influence of the PD despite these prior experiences is the lack of safety training educators reported receiving over the past three years. None of the participants had received any form of safety training or PD from their district, and as indicated in the supplemental post-survey question, some participants learned about topics they were either unaware of or had not heard about since their pre-service coursework many years ago.

This lapse in initial training and retraining is alarming due to OSHA (2015) standards explicitly addressing this issue. Bloodborne pathogen (OSHA Standard 1910.1030) and hazardous chemical (OSHA Standard 1910.1450) trainings must be provided by the district to all new employees who could be exposed to these hazards (e.g., science and T&E teachers, makerspace supervisors). Bloodborne pathogen refresher trainings should be administered annually, and chemical hazard trainings must be offered whenever new chemicals are to be used in the lab/makerspace (OSHA, 2015). Furthermore, NSTA (2015) recommends that training for any new hazard exposure situation and retraining occur on an annual basis. Even in states that have their own set of approved OSHA standards, it is better professional practice for school districts to provide updated safety training annually.

The variety among courses taught by participants and their certification areas demonstrated the vast interest in makerspaces that was also reflected in the literature. Of the participants who indicated they were involved in the initial planning and current supervision of their school's makerspace, none were teaching T&E classes and only one had T&E education certification. Computer science teachers, art teachers, and librarians reported being tasked with these makerspace responsibilities, supporting concerns raised in the literature about collaborating with T&E educators due to their unique safety training and expertise (Klein et al., 2016; Love & Roy, 2018b; NSTA, 2016). Furthermore, less than half (39%) of the participants stated their school currently had a makerspace, but in the supplemental post-survey question they mentioned that their school had plans to create one. Despite the interest from various content areas, there are still limited safety resources and trainings provided by professional educator associations. The exceptions to this are ITEEA (2018) and NSTA (2018) who have safety webpages and other helpful resources to assist their members with makerspace safety issues. Additional resources like these at the state level could help inform educators who are not receiving annual training from their district, however these resources should not supplant required training.

In analyzing the data for RQ2-SQ3, the researcher had to examine not only certification but also the content area in which the participant had taught. Certification can be deceiving because in the state where the study was conducted, certification merely meant that person passed the Praxis II exam in that content area (e.g., technology education). This would not guarantee that they graduated from a T&E teacher preparation program or completed coursework on safety and laboratory management that is often part of T&E teacher education programs (Litowitz, 2014). When examining safety perceptions, it is important to also consider past experiences that may have contributed to an educators' safety awareness, not merely their area(s) of certification.

It was expected that more teachers would have provided legally sound statements on the accident report form since they had just participated in a session examining liability, case law, and duty of care. A few participants cited this activity as one of the most influential experiences of the PD. This may suggest that authentic examples are needed in safety PD sessions to help teachers apply their safety knowledge related to complex issues (e.g., liability). Strategies for properly completing accident report forms are very important due to their potential legal ramifications. This is a topic that should be reviewed annually in school safety trainings and STEM department meetings.

Despite no statistically significant differences among gender and certification, the supplemental question in the post-survey revealed that almost all participants found the PD to be beneficial. Their feedback also provided suggestions for modifications that could be made to improve the PD experience and data collection in future safety studies.

Recommendations

The findings from this study lend themselves to providing recommendations for STEM educators, librarians, administrators, teacher educators, and researchers. Below are recommendations for practitioners and researchers.

Educators, School Districts, and Teacher Preparation Programs

Based on the lack of safety training participants reported receiving over the past three years and the significant influence of the PD, school districts should review their safety training timetable and policies. Districts or school consortiums must provide safety training to all new employees if they will be working with hazardous tools and chemicals. Individuals overseeing makerspaces or STEM labs would be exposed to such hazards. Additionally, whenever a new piece of equipment or chemical is obtained for use in the makerspace, the district must provide training on these items. It is strongly recommended that a safety refresher training be administered annually. In regards to bloodborne pathogens, districts are required to provide a refresher course each year (NSTA, 2015; OSHA, 2015).

Districts should also develop or review their existing safety policies for makerspaces. One excellent starting point would be Roy and Love's (2017) book. When developing makerspaces, schools should ensure all stakeholders are involved from the initial planning to the supervision. While libraries may have the physical capacity and staff to provide greater access to a makerspace, librarians may not have the level of safety training that a T&E teacher possesses. This is why collaboration is critical (Love & Roy, 2018b; Roy, 2014; Roy, 2015). Teacher preparation programs should stress the importance of collaboration for fostering safer STEM learning environments. Providing safety coursework or trainings for pre and in-service educators can help raise awareness about important considerations for makerspaces. Teacher preparation programs and school districts should also provide training on properly completing an accident report form following the recommendations presented by Love and Roy (2018a).

Researchers

There is a lack of research examining safety practices in school, university, and library makerspaces. Studies like this should be replicated on a larger scale and in areas that may provide a more diverse sample. The instrument used in this study could be administered to different educators and used to compare the makerspace safety perceptions among librarians, art, elementary, T&E, science, and computer science teachers. When conducting future research, it is recommended that researchers cover similar safety topics and allow for a full day PD experience. Additional data collection items (e.g., content analyses of current school/library makerspace rules and policy documents, pictures of existing makerspaces) should be included to provide a more in-depth analysis of makerspaces and safety practices. If possible, visits to observe makerspaces and educators' safety practices during instruction would be very informative.

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