Safer Engineering and CTE Instruction

A National STEM Education Imperative

What the Data Tells Us

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Safer Engineering and CTE Instruction
by Tyler S. Love and Kenneth Russell Roy

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https://www.iteea.org/SafetyReport.aspx

The bottom line: How can you use this information?

Be sure to read pages 97-101 for a summarized list of practical applications derived from the data in this study.

DISCLAIMER

This report is intended for use by all instructors, administrators, safety facilitators/consultants, chemical hygiene officers, parents/guardians, and professional education associations looking to facilitate safer hands-on science, technology, engineering, and mathematics (STEM) teaching and learning in informal community organizations and formal educational settings. Information included in this publication has been obtained from what the authors consider reputable sources; however, the authors do not assume liability for the accuracy of the information and do not imply that methodologies outlined are the only applicable ones. This book does not supersede legal safety standards (school, school district, local, state, or federal laws, regulations, codes, etc.) and better professional safety practices (ITEEA, ACTE, ASEE, NSTA, NSELA, ACS, etc.).

Each chemical spill incident is a unique occurrence and procedures for handling such spills may vary among emergency response teams. In this report the authors describe the usual steps taken during an emergency response incident, as well as any first aid treatment, if necessary. Furthermore, it suggests practical ways to prepare for an accident spill and to cooperate with emergency responders. However, the authors do not imply that these written suggestions are the only ways to prepare for, and assist in, an accident spill or first-aid emergency.

Resources cited and provided are intended as a supplement to the information in this book. The authors are not responsible for the contents or accuracy of the material obtained from legal safety standards (federal laws, regulations, codes, standards, organizations/sources [ITEEA, ACTE, ASEE, NSTA, NSELA, ACS, etc.], and other sources) and better professional safety practices.

This publication is intended to serve as a research-based resource for improving makerspace and STEM/CTE laboratory safety. Ultimately, it is the instructor's responsibility for teaching STEM and CTE courses of study safely while aligning with state and national standards. Boards of Education and school administrators must provide support and authority to enable teachers to do so. The authors are not responsible for what instructors do in the course of teaching STEM or CTE, or how they oversee makerspaces, Fab Labs, and STEM labs. Mention of any company or product does not constitute endorsement by the authors. In addition, the inclusion of links to particular items or websites is not intended to reflect endorsement by the authors, nor is it intended to endorse any views expressed or products or services offered by the author of the reference or the organization operating the server on which the reference is maintained.

The information contained in this publication has been effected and compiled by two internationally recognized safety compliance specialists, and both authors have been trained as authorized OSHA instructors. The opinions represent prudent safety practice on the subject based on OSHA and other legal safety regulations but do not purport to specify all legal standards. No warranty, guarantee, or representation is made by the authors as to the accuracy or sufficiency of the information contained therein. They are intended to provide basic guidelines in the areas of employee and employer safety and loss control/prevention.

Therefore, it cannot be assumed that all necessary warning and precautionary measures are contained in this information. Users of these services and information should also consult pertinent local, state, and federal laws and legal counsel for additional safety prevention program components.

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DEDICATION

The authors dedicate this book to STEM and CTE teachers, administrators, and advocates who work tirelessly to provide a safer hands-on teaching and learning experience for our country's future problem solvers and innovators. We especially thank those who dedicated their time to participate in this study and help make STEM education and CTE safer.

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Dr. Kenneth Russell Roy has been a science/mathematics educator, K–12 administrator, and safety compliance officer/specialist for more than 50 years. In addition, he has a large number of experiences as an author and editor, with more than 800 published articles and 12 books addressing K-12 science education and laboratory safety. He has served in numerous leadership positions for state, national, and international science education organizations. He presently serves as the Director of Environmental Health and Safety for Glastonbury Public Schools (Glastonbury, Connecticut). He concurrently serves as Chief Science Safety Compliance Adviser and Chief Safety Blogger for the National Science Teaching Association (NSTA) and Safety Compliance Officer for the National Science Education Leadership Association (NSELA). Dr. Roy is also an independent safety compliance consultant and advisor working for professional organizations, school districts, magnet schools, insurance companies, textbook publishers, state departments of education and other organizations dealing with safety and science/technology and engineering education issues. He specializes in working with science and, technology and engineering education departments in K–12 schools relative to science labs, STEM labs, Fab Labs and makerspaces safety compliance issues (site designs, mock OSHA inspections for existing facilities, safety plan development, employee safety training, etc.). He serves as an expert witness in legal cases involving K–12 laboratory accidents. Dr. Roy earned a bachelor's degree in science education in 1968 and a master's degree in 1974, both from Central Connecticut State University, and doctorate in 1985 from the University of Connecticut. In addition, he received a diploma in professional education from the University of Connecticut in 1981 and a Certificate of Instruction as an authorized OSHA instructor from the Keene State College OSHA Extension School.

Dr. Roy is a past chairperson of the NSTA Safety Advisory Board. He is an NSTA author and chief safety blog columnist. He has served as president and executive director of NSELA. He also was the North American Representative for eight years and chairperson of the safety committee for the International Council of Associations for Science Education (ICASE).

SECTION I

PROJECT BACKGROUND

INTRODUCTION

It is indisputable that safety plays a critical role in our daily lives. From the equipment we use in our kitchen to the advanced safety features in our vehicles, safety is a core consideration in every scientific discovery and technological and engineering innovation. Safety is also an enduring concept – one that has been a core component of early manual arts and science programs to present day design-based STEM (science, technology, engineering, and mathematics) instruction in laboratories, makerspaces, Fabrication Labs (Fab Labs), libraries, community centers, and outdoor education programs[1]. Regardless of our geographical location or personal beliefs and characteristics, safety affects us all and is critical for preparing STEM-literate students who are career and college ready[2].

National data on young worker health and safety illustrates the need for improving students' safety knowledge and practices. The National Institute for Occupational Safety and Health (NIOSH) reports that 12% of the U.S. workforce is under the age of 24, and the rate of work-related injuries among this group is 1.25 times greater than that of other age groups[3]. Furthermore, research findings highlight the dire need for improving students' safety knowledge and practices within STEM-related courses. Despite advancements in safety research, instructional delivery capabilities and resources, facility designs, equipment safety features, engineering controls, and personal protective equipment (PPE), studiesfrom 2001-2022 have reported a sustained lack of safety training, PPE, engineering controls, safety practices, and an increase in the percentage of minor and major accident occurrences within science and technology and engineering education (T&E) courses[4]. STEM and CTE (career and technical education) programs are critical more than ever as they not only prepare students with valuable content knowledge, but they also prepare students with practical skills that are applicable beyond school. STEM and CTE educators play an integral role in not only providing safer learning environments, but also teaching students essential safety skills that they can transfer to their career and daily life.

To better understand what is meant by STEM education safety and analyze the results presented in later sections, the term STEM must first be operationally defined according to how it is used within the context of this book.

Defining STEM

Within the context of this book, T&E refers to the application of design processes, most notably engineering design, to develop a product or system, or solve a problem that could utilize a broad range of tools, machines, and processes[5]. Furthermore, within this book STEM is used in reference to science, T&E, career and technical education (CTE), and integrated STEM activities, which could include observations, hands-on investigations, explorations, demonstrations, and/or field activities and investigations. These activities could encompass crosscutting teaching and learning opportunities that integrate concepts from additional content areas (mathematics, the Arts, etc.). STEM education safety is applicable across science, T&E, CTE, and other content areas involving scientific inquiry, engineering design, science and engineering practices, problem-based learning, design-based learning, and career and college readiness.

Providing safer STEM and CTE instruction has become increasing challenging in many aspects, especially with the shift to more interdisciplinary hands-on teaching and learning. Although this has helped to engage students in authentic and rigorous learning experiences, it has also multiplied the potential safety hazards and resulting risks that instructors must be knowledgeable about and prepared to proactively address. This is most evident in collaborative learning environments like makerspaces, Fab Labs, and STEM labs where instructors are responsible for overseeing a multitude of biological, chemical, and physical hazards with resulting risks. Hence, proper facilities design, safety training, safety policies and practices, and other proactive measures are imperative[4,6]. The importance of implementing proper safety practices when delivering hands-on interdisciplinary STEM and CTE instruction is exemplified in the accident described in Case Study A[7].

Case Study A: STEM Class Potato Gun Accident

An eighth grade student in Palo Alto Unified School District (California) was injured by a potato gun constructed by his teachers as part of an experiment for a middle school mathematics class. A bicycle pump was used to pressurize the chamber of the potato gun, and the potato was intended to be shot as a valve on the top of the gun was opened. When it was the student's turn to operate the potato gun he turned the valve, but the gun did not fire. Several seconds later, the gun suddenly discharged and the potato hit the student in the face. The incident permanently damaged the student's retina, and caused an orbital fracture, a traumatic injury to the bone of the eye socket. He was homebound for several months after the experiment. The potato gun experiment was conducted by two math teachers, one of whom was a volunteer with no teaching credentials. The student's parents alleged that the school district and teachers breached their duty to conduct the experiment "with reasonable care" and to protect the student from "foreseeable dangers." They also claimed that the adults supervising the class (two math teachers and a volunteer) failed to provide proper supervision, appropriate protective equipment, and adequate safety training before using a homemade and defective potato gun. The school district settled out of court for $1.5 million. The settlement included attorney's fees and reimbursement for medical expenses[7].

Love[8,9] described a number of examples where courts cited prior verdicts from P-12 science education, technology and engineering (T&E) education, and CTE accident cases as the precedent applicable across these areas. The scenario described in Case Study A demonstrates the increased potential for hazards and resulting risks that teachers must be prepared to address when delivering hands-on experiential learning experiences that integrate concepts from multiple content areas.

A potato gun that exploded.
Photo Credit: Explosion by Eli Christman. CC BY 2.0 license.

SECTION II

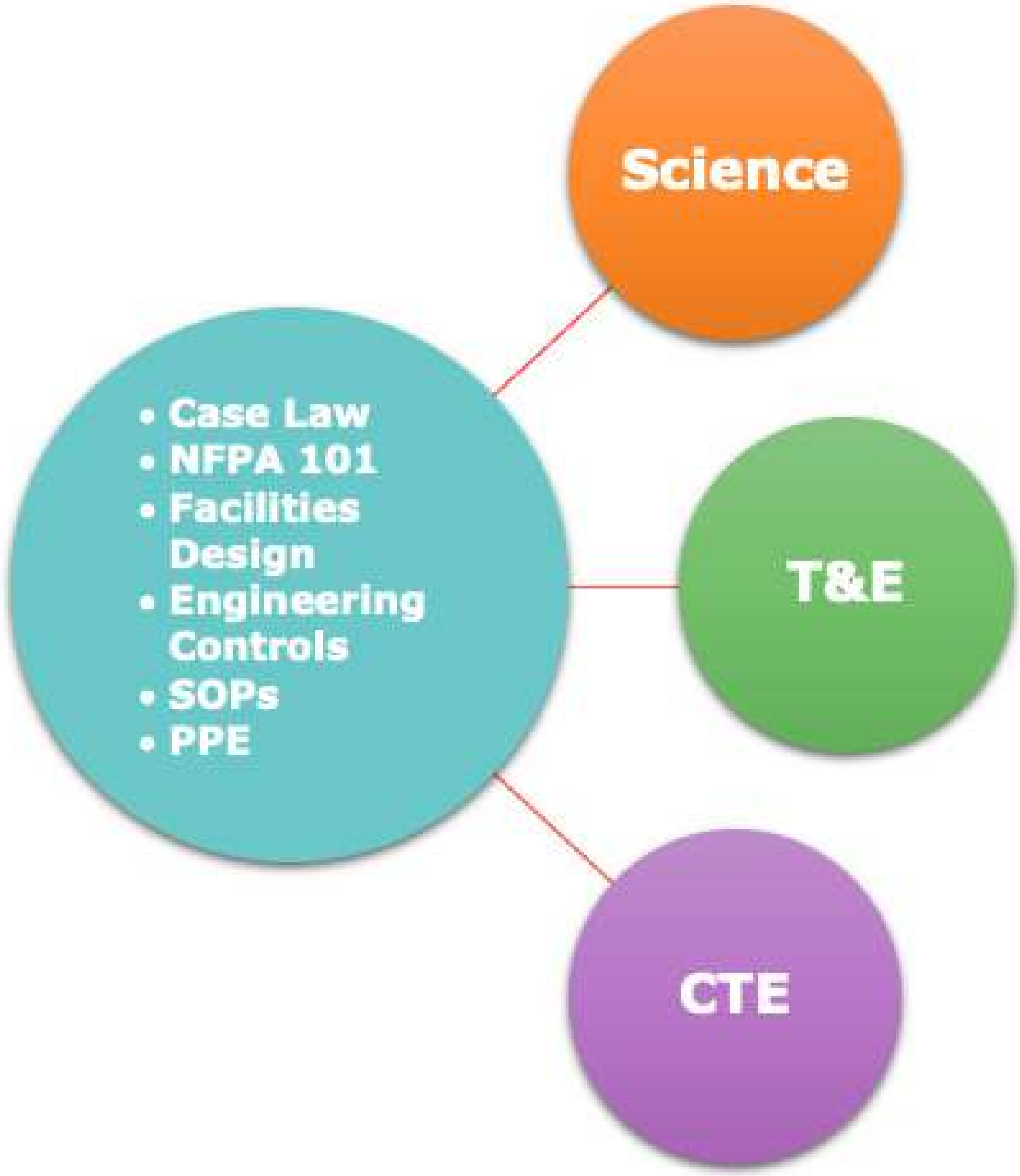
EXAMINING SAFETY ACROSS STEM EDUCATION AND CTE

CONCEPTUALIZING SAFETY INSTRUCTION

To better prepare teachers for addressing safety issues, one must first gain an understanding of how safety has been conceptualized within the context of STEM and CTE education. DeLuca et al.[10] viewed safety as having three domains: 1) cognitive (knowing about safer practices), 2) affective (having the desire to maintain a safer learning/working environment and a proper attitude toward safer practices), and 3) psychomotor (the physical ability to perform safer practices). Additionally, they described how environmental influences (e.g., facilities characteristics) and outside influences (e.g., public agencies and professional organizations) can contribute to safer teaching and learning. DeLuca et al.'s[10] conceptualization of safety illustrates the importance of not only addressing facility design needs and the physical actions of students, but also addressing their attitudes toward safety and knowledge of important safety concepts. DeLuca et al. concluded that this approach could apply to safer teaching and learning across STEM content areas.

Much can also be learned about safety instruction from CTE. Threeton and Evanoski[11] examined safety from the lens of three major learning theories (behaviorism, cognitivism, and social learning theory) used by career and technical educators to teach about occupational safety and health (OSH) practices. As described by Threeton and Evanoski[11], behaviorism focuses on teaching safety practices (usually through hands-on activities) and ensuring students demonstrate a required level of competency in safety behaviors. This is often achieved through positive reinforcement and comparing students' behaviors to industry safety standards. Cognitivism focuses on developing learners from lower-order to higher-order thinking skills (e.g., Bloom's taxonomy), which can be accomplished by using multiple instructional methods (lectures, hands-on activities, virtual modules, online videos, etc.). Lastly, social learning theory focuses on observing modeled behaviors while interacting with others. This could involve acquiring safety skills in a CTE class and observing how they are applied in a work environment through a CTE cooperative work experience[11]. When examining safety from this perspective, Threeton and Evanoski[11] found that most teachers attempt to model safer behaviors and share their personal safety experiences with students during instructional activities as a method to promote safer habits.

SAFETY CONNECTIONS ACROSS STEM EDUCATION AND CTE



Examples of Safety Connections Across Science Education, T&E Education, and CTE.

Note: NFPA 101 = Life Safety Code (specifically occupancy loads for labs and shops); SOPs = Standard Operating Procedures; PPE = Personal Protective Equipment. While there is general overlap in these areas, in certain cases there may be slight differences tailored to potential hazards and resulting risks in a specific discipline and/or facility.

T&E EDUCATION AND CTE

While science education, T&E education, and CTE have some distinct differences, there is much overlap in regard to safety practices and emerging legal precedent that can inform the content taught in these areas[2,8]. The overlap among T&E education and CTE is apparent when examining how state education departments categorize T&E programs. In an analysis conducted by Bartholomew et al.[12] it was discovered that T&E programs in most states fell under the supervision of the state's CTE division. They attributed this to the classification of instructional programs (CIP) codes for the courses offered by T&E programs, which were closely related to CTE program areas (e.g., industrial-based courses). From this it is plausible to expect that there is also considerable overlap among T&E and CTE programs regarding the safety concepts they teach about similar tools, equipment, and processes (hand and power tools, woodworking equipment, metalworking equipment, CNC machines, etc.).

SCIENCE EDUCATION AND T&E EDUCATION

There is also a considerable amount of overlap among science education and T&E education programs. Since the release of *Next Generation Science Standards* (*NGSS*)[13], science educators have been expected to teach engineering content and practices, which often includes the use of hazardous hand and power tools to construct models and prototypes[14,15]. While science teacher preparation programs include methods courses that often cover safety related to myriad biological, chemical, and physical hazards, science educators often do not receive training on safety practices and classroom management related to engineering hand and power tools[16,17]. Additionally, at the elementary level, teachers are being encouraged to integrate more hands-on science and engineering practices, but with very limited to no safety training in helping young students to safely design and construct prototypes. This poses safety concerns and can cause elementary teachers to be hesitant about implementing such design-based learning experiences[18]. This lack of safety training, despite the expectation to supervise students while safely constructing their designs, is alarming, especially when teachers are attempting to teach interdisciplinary STEM activities like the example described in Case Study A[7]. Science and T&E education safety specialists have suggested the best remedy for helping science and elementary educators provide safer

engineering instruction is to collaborate with T&E educators who have completed specialized training in this area as part of their teacher preparation or certification program[14,15,19,20].

SCIENCE EDUCATION, T&E EDUCATION, AND CTE

Further overlap among the safety policies and practices in science education, T&E education, and CTE areas is noticeable from the application of seminal research on lab occupancy loads. Stephenson et al.[21] found that the rate of accidents in P-12 science labs significantly increased when enrollment exceeded 24 students, when square footage dropped below 60 square feet per student, and when room/lab size was less than 800 square feet. Additionally, Stephenson et al.[21] found that 35% of science teachers did not have adequate safety training and 69% did not have a written safety policy for their classes. That study was replicated eleven years later and yielded similar results[22]. The National Fire Protection Association (NFPA) 101 Life Safety Code specifies that laboratories and shops in school settings require two and a half times more square footage per occupant (50 square feet) than classrooms where non-laboratory activities are being conducted (20 square feet). The terms "laboratories" and "shops" encompasses science labs, T&E labs, CTE labs, makerspaces, Fab Labs, and other learning environments where hands-on STEM and CTE instruction take place. Most states have adopted the NFPA 101 Life Safety Code, which applies to labs and makerspaces utilized by science education, T&E education, and CTE programs. In this way, Stephenson et al.'s research has been cited frequently by state education departments and professional associations such as the National Science Teaching Association (NSTA)[23,24] and the International Technology and Engineering Educators Association (ITEEA)[25] in regard to safer occupancy load recommendations.

The above examples illustrate there is clearly overlap among the safety needs, available resources, and research from science education, T&E education, and CTE areas. State education departments, administrators, teachers, teacher preparation faculty, and others would be wise to review safety resources from each of these content areas and utilize or adapt those resources to be more content-specific when warranted.

SAFETY IN STANDARDS, FRAMEWORKS, AND TEACHER PREPARATION DOCUMENTS

SCIENCE EDUCATION

While it is evident that safety plays a critical role in science education, T&E education, and CTE, the inclusion of safety criterion in national and state standards documents, frameworks, and teacher preparation guidelines are critical to ensuring that safety remains a core focus of STEM and CTE teaching and learning. A content analysis conducted by a panel of safety specialists from across the U.S. revealed that overall there was not a large focus on safety throughout national STEM and CTE content standards and frameworks[26]. That study found that in many of the documents safety was either not a major consideration, or was included as a stand-alone standard or concept that was not embedded throughout the document in benchmarks or sub-concepts that presented potential hazards and resulting risks. In science education, although NSTA has a Safety Advisory Board (SAB) that is charged with publishing white papers and other safety resources annually, there are limited references to safety in *A Framework for K-12 Science Education*[27] and a substantial lack of focus on safety within the NGSS[26,28]. However, as Love et al.[26] pointed out, the *Standards for Science Teacher Preparation*[29] later placed an increased emphasis on safety after concerns were raised by NSTA's SAB about the NGSS[28]. Furthermore, a consensus study report by the National Academies of Sciences, Engineering, and Medicine[30] also found that the expectation for science educators to teach engineering practices had elevated safety concerns. They cited science educators' lack of preparation to safely deliver engineering design instruction that often involved the safe use of hand and power tools as one area of imminent concern.

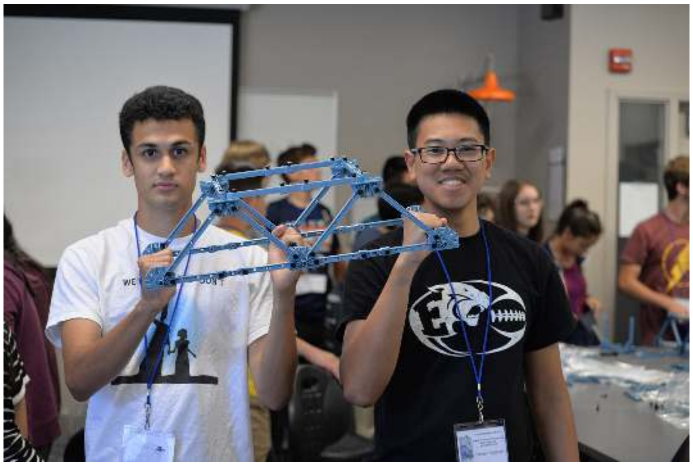


Photo Credit: Penn State Harrisburg, Sharon Siegfried.

At the state level, some states have integrated safety considerations as a key aspect of their facilities, requirements, and state content standards. Since 1993 Texas has included a focus on safety design considerations for science facilities within its State Board of Education *Commissioner's Rules Concerning School Facilities*[31]. The school science facilities standards in Texas were initially created to address problems resulting from over-

Safety Note: Photo shows young students working with liquids and having only eye protection (i.e., safety goggles) for personal protective equipment (PPE). Potential hazardous liquids warrant additional PPE for hands (e.g., nitrile gloves) and body (e.g., non-latex apron or lab coat). Also, liquid containers need to be labelled.

crowding (square footage, class size, etc.) and continue to address those issues. Additionally, safety criteria is specifically included in the Texas science content standards, and the Texas Education Agency (TEA) has developed best safety practices documents, along with other resources[32], to advocate for safer science teaching and learning.

ENGINEERING EDUCATION

To address concerns regarding the expertise required to safely integrate science and engineering practices, documents published via the American Society for Engineering Education (ASEE), NSTA, and ITEEA journals and websites have all advocated for collaboration among science and T&E educators as the preferred method to teach interdisciplinary STEM in a safer manner[9,14,15]. When specifically focusing on safety in engineering education, safety is often discussed from the lens of designing and testing products with user safety in mind (an ethical obligation). While this is another important facet of safety and engineering design, it should not overshadow the safety practices that students and engineers must follow to safely develop and test prototypes and design solutions. Lomask et al.[33] demonstrated an important balance between incorporating safety as both an ethical consideration and as a practical skill when designing and fabricating solutions. Safety practices are included as a core component of the practical learning and prototyping criteria within their *Engineering for All* Design Teaching Standards and Teaching Performance Rubrics on Design Practices. Furthermore, TEA's criteria for certification in Grades 6-12 Mathematics/Physical Science/Engineering also emphasizes the need to prepare educators with a strong background in safety from both an ethical and practical sense. Domain VII specifically focuses on safety competencies that teachers should be able to demonstrate to earn their teaching certification in this area.

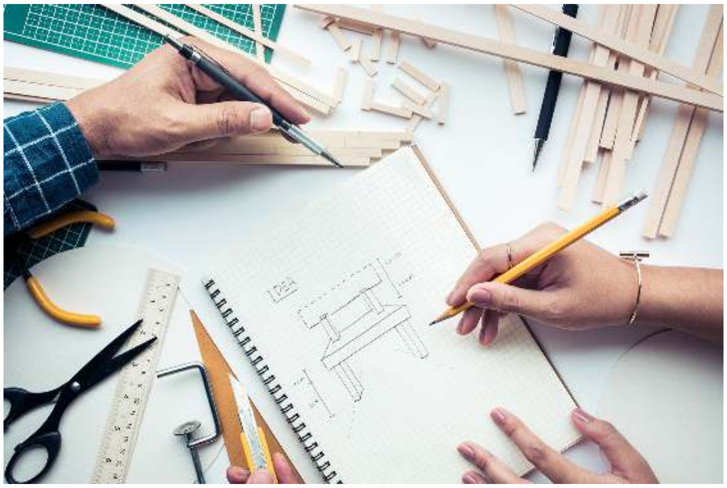
Photo Credit: Penn State Harrisburg, Sharon Siegfried.

CTE

Safer practices, research, and resources from both science education and T&E education have been found to be applicable in CTE programs[34]. Safety instruction has been identified as one the top competencies that administrators and CTE teachers believe is needed to successfully manage a CTE course[35,36]. As a result of the perceived importance of safety in CTE programs, there has been a wealth of valuable safety research and resources borne out of CTE, especially in pathways such as agriculture education, automotive technology, and construction. Threeton and Evanoski's[11] research presented a number of factors that teachers believed were obstacles to managing safety in CTE courses. These obstacles mirror common concerns expressed by science and T&E educators. Moreover, element 7 of the Association for Career and Technical Education's (ACTE) framework for quality CTE programs focuses heavily on safety[37]. This framework outlines the need for facilities, materials, equipment, maintenance, and practices to meet local, state, federal, and industry standards. It also focuses on students' ability to demonstrate appropriate and safer usage of facilities, equipment, and materials. Within ACTE there are a number of Divisions, such as Engineering and Technology Education, which also include a section dedicated to STEM education. This is just one of a number of ACTE divisions and sections that share common safety criteria with science education and T&E education programs. Examples of the closely related safety criterion among these areas are discussed by West and Motz[34]. They described how the same federal safety standards regulating engineering controls and occupancy loads in science and T&E labs can apply to CTE facilities. This level of overlap may be one reason why states like Kentucky have created a guide that includes design considerations and safety recommendations for both CTE and T&E facilities in the same document[38]. Similarly, Massachusetts has adopted a guide encompassing design considerations and safety recommendations for science and T&E learning spaces, including makerspaces and integrated science, technology, engineering, the Arts, and mathematics (STEAM) labs[39].

T&E EDUCATION

The content analysis conducted by Love et al.[26] revealed that the standards or framework document with the greatest emphasis on safety was *Standards for Technological and Engineering Literacy* (*STEL*)[5]. Their study found that *STEL*, unlike many other documents analyzed, embedded critical safety concepts across multiple standards and benchmarks, T&E practices, and T&E context areas throughout the document as opposed to making it a single stand-alone standard. This supports Haynie's[40] recommendation that safety should not be a one-time occurrence, but rather an integral part of all aspects of T&E education. Some states like Kentucky have emphasized the importance of safety by dedicating an entire section of their T&E content standards to safety, which includes multiple safety instructional standards and benchmarks informed by state occupational safety and health regulations[41]. These standards have direct implications for informing facility design/renovation considerations, curriculum development, and instructional/learning practices. Explicitly including key safety concepts like this in national and state standards is one method that helps educators advocate for critical safety resources and policies in collaboration with their with their administrators, curriculum developers, school safety officer/chemical hygiene officer, and local board of education members.



SECTION III

PURPOSE AND METHODS

PURPOSE OF THIS PUBLICATION

Safety is an enduring concept that has been one of the cornerstones of science, T&E, and CTE instruction for decades[1]. It will remain one of the most important concepts across these content areas as educators continually strive to keep student and instructor safety as their number one priority in STEM education and CTE. Haynie[40] may have captured the timeless nature of safety best when he said, "The smaller machines are well guarded, have less power, and simply do not appear as intimidating and dangerous. That's the problem!" (p. 31). Educators have witnessed the evolution of this concern with the popularity of makerspaces and interdisciplinary STEM activities. Although some of today's tools and equipment look safer and less intimidating than those of years ago, they still require important safety training and supervision since they perform the same functions and can be just as dangerous if not used properly! As new technologies, equipment, systems, and processes emerge there will be advances in safety features, yet new types of potential hazards and resulting risks may also emerge. This is why safety must remain at the core of STEM education and CTE—it will forever remain relevant.

While educators are aware that the growing expectation to provide interdisciplinary learning opportunities places greater demands on teachers, especially in regard to safety training and practices, there is very limited empirical data to help address such safety concerns[19,42]. **Hence, the overarching purpose of this publication is to present sound research findings about regional and national safety factors, safety characteristics of facilities, and instructor and student safety practices relative to STEM and CTE learning spaces.** Our hope is that this publication will provide the much-needed data and research-supported recommendations to raise levels of awareness about the need to improve and/or adopt updated STEM and CTE safety policies and practices for a safer teaching and learning experience. In addition to the need to adopt updated safety policies and practices, we hope this book will support requests for necessary safety resources needed by professional education associations, state education departments, teacher preparation programs, administrators, school districts, teachers, and others (e.g., community makerspaces).

RESEARCH METHODOLOGY

To provide transparency regarding how this study was conducted, we describe our research methodology in this section. Research approval for this project was granted by the Office of Research Protections at The Pennsylvania State University in April 2019 (Study ID 00012283).

Survey Instrument

The 2020 T&E Education - Facilities and Safety Survey (TEE-FASS) was used to collect responses via online survey software in the spring of 2020. The TEE-FASS was developed from the 2001 Texas Science Safety Survey[21] and slightly modified to represent emerging safety issues and practices related to STEM education. This instrument asked a series of questions related to 1) demographics, 2) educator experience and certification, 3) classroom conditions, 4) facilities characteristics, and 5) teacher and student safety training, accidents, and safety incidents. To establish face validity, the instrument was reviewed by three national STEM education safety specialists and pilot tested among a small sample of STEM teachers to make additional changes. It was then advertised by state and national STEM education associations (especially T&E education and CTE professional associations) which yielded responses from ***718 teachers across 42 states***[42].

The TEE-FASS survey instrument can be accessed at: https://www.iteea.org/SafetyReport.aspx

Limitations

As with any study there are a few limitations that should be considered when interpreting the results. The data was voluntarily self-reported by teachers from 42 U.S. states. Although the survey was administered in April 2020, shortly after the COVID-19 pandemic caused schools to transition to online teaching and learning, the participants did have face-to-face classes for the majority of the 2019-2020 academic year on which to report. Although this study included a broad sample of teachers, the results may not be generalizable to every teacher, school district, or state. However, this research does provide a much broader sample in comparison to previous safety studies that included educators from a local region or within a single state.

GEOGRAPHICAL REGIONS

The results from this study are reported both nationally and according to region. The regions were determined according to the U.S. Census Bureau's Regional Divisions. The Pacific and Mountain divisions comprised the west region, the west north central and east north central divisions comprised the Midwest region, and the west south central and east south central divisions comprised the south central region. Due to small number of responses from those six divisions, they were reported according to region. This publication presents the data according to the regions specified in the table on the following page. This allows readers to view the results that best represent the programs and practices within their region. Additionally, this provides the opportunity to compare regional results to the national average.

Results from this study have also been reported specifically to individual states via conference presentations and webinars. To access those results please see the resources listed in Appendix B (pg.121) or visit the website for this project:

https://www.iteea.org/SafetyReport.aspx

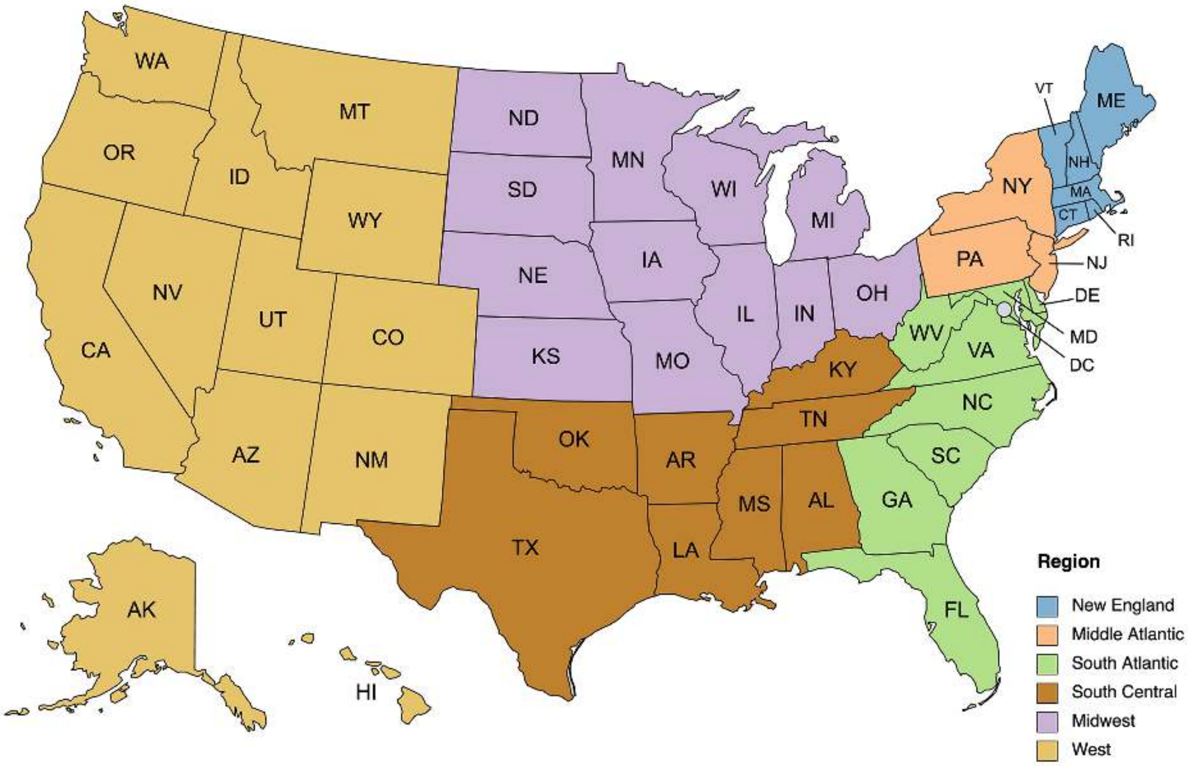


Photo Credit: Mapchart.net

Region	States		
New England n = 74	• Connecticut • Maine	• Massachusetts • New Hampshire	• Rhode Island • Vermont
Middle Atlantic n = 117	• New Jersey	• New York	• Pennsylvania
South Atlantic n = 240	• Delaware • District of Columbia • Florida	• Georgia • Maryland • North Carolina	• South Carolina • Virginia • West Virginia
South Central n = 65	• Arkansas • Alabama • Kentucky	• Louisiana • Mississippi • Oklahoma	• Tennessee • Texas
Midwest n = 151	• Illinois • Indiana • Iowa • Kansas	• Michigan • Minnesota • Missouri • Nebraska	• North Dakota • Ohio • South Dakota • Wisconsin
West n = 71	• Alaska • Arizona • California • Colorado • Hawaii	• Idaho • Montana • Nevada • New Mexico	• Oregon • Utah • Washington • Wyoming

SECTION IV

FINDINGS AND SUMMARIES

How can you apply these findings?

Be sure to read pages 97-101 for a brief list of practical applications summarizing the findings presented in this section.

DEMOGRAPHICS

The demographic results from this study revealed some interesting and important information related to safety, and more broadly, the types of STEM-related courses educators are teaching. The majority of participants who completed the TEE-FASS identified as male (74%) and white (90%). There was a range of teaching experience across the years of experience categories. The majority of respondents (95%) were secondary teachers with 50% possessing a degree at any level in T&E education or a master's in a non-STEM related education area (29%). Seventy-eight percent of the participants were certified to teach T&E education. T&E literacy (37%), materials processing (19%), and pre-engineering (16%) were the most popular course topics taught by participants, with course foci varying considerably by region.

The full demographic results and more detailed summaries about these results can be found in Appendix A (pg. 111).

PERCENTAGE OF CLASS TIME SPENT FACILITATING HANDS-ON T&E/STEM ACTIVITIES EACH WEEK

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
0-10%	3 (4)	1 (1)	9 (4)	1 (2)	1 (1)	2 (3)	17 (2)
11-25%	2 (3)	4 (3)	22 (9)	14 (22)	3 (2)	5 (7)	50 (7)
26-40%	10 (14)	11 (9)	47 (20)	10 (15)	9 (6)	5 (7)	92 (13)
41-60%	21 (28)	38 (33)	75 (31)	20 (31)	59 (39)	27 (38)	240 (33)
≥ 60%	38 (51)	63 (54)	87 (36)	20 (31)	79 (52)	32 (45)	319 (44)

Summary: The majority (77%) of teachers reported engaging their students in hands-on T&E/STEM activities for more than 40% of their weekly class time, with 44% of teachers spending more than 60% of class time facilitating hands-on T&E/STEM activities. The south central region had a large percentage of teachers spending less than one quarter of their weekly instructional time facilitating hands-on T&E/STEM activities, and the west had the largest percentage of teachers engaging students in hands-on T&E/STEM activities for more than 40% of the instructional time each week. Hands-on instruction is critical to STEM and CTE education. As the percentage of instructional time involving hands-on activities increases, there will inherently be a greater chance of safety incidents or accidents occurring. This is not suggesting the amount of hands-on instructional time be reduced. Rather, close attention should be given to facility designs, safety policies, and safety practices to help mitigate the risk and severity of an incident or accident. Love et al.[42] and the Statistical Analyses (pg. 96) section of this book describe the correlation found between accident rates and hands-on instructional time.

COURSE PREPS PER SEMESTER

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
1	6 (8)	3 (3)	10 (4)	3 (5)	2 (1)	1 (1)	25 (4)
2	7 (10)	19 (16)	50 (21)	8 (12)	12 (8)	7 (10)	103 (14)
3	25 (34)	35 (30)	99 (41)	11 (17)	26 (17)	26 (37)	222 (31)
4	24 (32)	30 (26)	44 (18)	17 (26)	47 (31)	14 (20)	176 (25)
5	7 (10)	15 (13)	20 (8)	11 (17)	26 (17)	11 (16)	90 (13)
>5	5 (7)	15 (13)	17 (7)	15 (23)	38 (25)	12 (17)	102 (14)

Summary: The majority of teachers reported having three course preparations (preps) per semester (31%), followed by four course preps per semester (25%). A surprisingly high percentage of teachers (14%) reported having more than five preps per semester. The south central and Midwest regions had a higher percentage of teachers with five or more preps per semester than other regions. Although additional course preps can help in offering a greater variety of courses, this places additional responsibilities on teachers that can detract from their time to address safety and facility issues (e.g., setting up machine jigs, prepping materials and equipment prior to class). Additionally, research has shown that a loss or lack of course prep time places additional stress on teachers and accidents can increase when teachers have more than two preps in a semester, and other safety related issues result[43] (e.g., fatigue). School administrators should work in collaboration with school counselors and educators to ensure instructors have adequate prep time, especially for courses that require additional preparation time to maintain safer teaching and learning conditions (e.g., manufacturing courses compared to computer aided design [CAD] courses). Moreover, there are numerous resources to help educators in preparing their lab or makerspace for a new school year[44] or summer break[45].

ADMINISTRATION’S PROGRESSIVE DISCIPLINARY SUPPORT AND SUFFICIENT BUDGET FOR SAFETY

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Administrative Support							
Excellent	23 (31)	37 (32)	50 (21)	19 (29)	43 (29)	12 (17)	184 (26)
Good	30 (41)	50 (43)	89 (37)	29 (45)	67 (44)	38 (54)	303 (42)
Fair	13 (18)	23 (20)	60 (25)	13 (20)	26 (17)	17 (24)	152 (21)
Poor	8 (11)	7 (6)	41 (17)	4 (6)	15 (10)	4 (6)	79 (11)
Budget							
Yes	48 (65)	69 (59)	118 (49)	26 (40)	74 (49)	45 (63)	380 (53)
No	26 (35)	48 (41)	122 (51)	39 (60)	77 (51)	26 (37)	338 (47)

Summary: Most respondents rated their school administrators’ support as good (42%) or excellent (26%). However, participants were not as optimistic about the budgetary support received. Only 53% indicating they felt they had a sufficient budget for safety. Specifically, the New England, mid-Atlantic, and west regions had a higher percentage of respondents who believed they had a sufficient budget for safety. Conversely, the south central region had a large percentage of educators who believed they did not have a sufficient budget. School districts should ensure an appropriate amount of money is budgeted annually for safety training, equipment upgrades, guards, PPE, engineering controls, maintenance, and other safety-related costs to maintain a safer teaching/learning environment in accordance with state and/or federal occupational safety and health standards.

CLASS ENROLLMENT AND SUFFICIENT WORKSPACE

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Average Class Enrollment							
<15	18 (24)	18 (15)	11 (5)	6 (9)	28 (19)	5 (7)	86 (12)
16-20	29 (39)	54 (46)	72 (30)	27 (42)	47 (31)	9 (13)	238 (33)
21-24	21 (28)	29 (25)	63 (26)	10 (15)	37 (25)	16 (23)	176 (25)
25-30	5 (7)	9 (8)	74 (31)	14 (22)	32 (21)	26 (37)	160 (22)
>30	1 (1)	7 (6)	20 (8)	8 (12)	7 (5)	15 (21)	58 (8)
Largest Class Enrollment							
<15	9 (12)	7 (6)	3 (1)	4 (6)	5 (3)	3 (4)	31 (4)
16-20	22 (30)	31 (27)	39 (16)	12 (19)	18 (12)	1 (1)	123 (17)
21-24	21 (28)	34 (29)	45 (19)	8 (12)	39 (26)	8 (11)	155 (22)
25-30	20 (27)	37 (32)	82 (34)	26 (40)	58 (38)	20 (28)	243 (34)
>30	2 (3)	8 (7)	71(30)	15 (23)	31 (21)	39(55)	166 (23)
Have Sufficient Student Work-space*	43 (58)	67 (57)	151 (63)	41 (63)	85 (56)	47 (66)	434 (60)

Note. * = Participants were asked if they believed there was six square feet of workspace per occupant at all tables and workbench-es.

Summary: Approximately 60% of teachers believed they had sufficient workspace in their lab. Moreover, 57% of respondents nationally reported their largest class enrollments included 25 or more students. Based on legal safety standards and better professional safety practices, this could be considered a safety issue relative to the teachers' duty of care for direct supervision. This could potentially exceed the occupancy load requirements mandated by the NFPA 101 Life Safety Code[23-25]. This, coupled with 40% of the respondents indicating that they had insufficient student workspace, poses serious concerns. Research indicates that when net square footage in STEM education labs falls below 60 square feet per occupant, and when enrollment exceeds 24 students per instructor, the chance of an accident increases significantly[21-25,34]. Better professional safety practice informed by these research findings suggests that there are no more than 24 occupants in a STEM lab or makerspace to reduce the chance of an accident.

However, it must be noted that the 24-occupants recommendation only applies if there is 50 net square feet per occupant (1,440 total net square feet). If a facility is smaller than this, the occupancy load should be determined by providing no less than 50 net square feet per occupant.

Example of an overcrowded classroom.
Photo Credit: Common classroom by Robert Couse-Baker. CC BY 2.0 license.

PERCENTAGE OF STUDENTS WITH A DISABILITY IN COURSES

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
0-5%	10 (14)	16 (14)	56 (23)	26 (40)	17 (11)	21 (30)	146 (20)
6-15%	38 (51)	52 (44)	98 (41)	22 (34)	59 (39)	28 (39)	297 (41)
16-25%	17 (23)	35 (30)	56 (23)	13 (20)	55 (36)	15 (21)	191 (27)
26-50%	6 (8)	12 (10)	26 (11)	4 (6)	18 (12)	7 (10)	73 (10)
>50%	3 (4)	2 (2)	4 (2)	0 (0)	2 (1)	0 (0)	11 (2)

Summary: As highlighted in Threeton and Evanoski's[11] research, teachers believed the percentage of students with disabilities enrolled in their courses (with no additional aid to assist) was one of the top factors that impacted safety. The south central region reported a much lower percentage of students with disabilities in their courses, and the Midwest reported a higher percentage compared to other regions. Nationally, 41% of respondents reported 6-15% of their students had a disability, followed by 27% noting that 16-25% of their students had a disability. Without additional qualified support in the lab, a high percentage of students with disabilities enrolled in a course can present challenges from both an instructional and safety perspective. There are a number of excellent resources with recommendations and strategies to make safer accommodations and modifications in labs and makerspaces[46-48].

Photo Credit: DO-IT Center, University of Washington.

WHEELCHAIR ACCESSIBILITY

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Have lab stations or workbenches that are wheelchair accessible	39 (53)	55 (47)	104 (43)	32 (49)	62 (41)	42 (59)	334 (47)

Summary: Almost half (47%) of the teachers in this study reported having lab stations or workbenches that were wheelchair accessible. The west region reported a much higher percentage of schools (59%) that had these lab stations or work benches than other regions. Teachers should work with the special education department in their school ensure they are providing the required yet appropriate accommodations while not jeopardizing the safety of themselves or others in the instructional space. There are a number of resources that provide recommendations for working with your school district's special education department to make the appropriate modifications or accommodations for students[46-48].

Photo Credit: DO-IT Center, University of Washington.

TEACHER SAFETY TRAINING AND COURSEWORK

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Undergrad course work							
T&E/STEM methods courses	5 (7)	5 (4)	7 (3)	2 (3)	14 (9)	5 (7)	38 (5)
Technical courses	9 (12)	14 (12)	29 (12)	8 (12)	22 (15)	10 (14)	92 (13)
Both methods and technical courses	36 (49)	82 (70)	105 (44)	17 (26)	74 (49)	38 (54)	352 (49)
None	24 (32)	16 (14)	99 (41)	38 (59)	41 (27)	18 (25)	236 (33)
Graduate course work							
T&E/STEM methods courses	9 (12)	6 (5)	20 (8)	6 (9)	10 (7)	2 (3)	53 (7)
Technical courses	2 (3)	4 (3)	15 (6)	2 (3)	5 (3)	1 (1)	29 (4)
Both methods and technical courses	21 (28)	28 (24)	61 (25)	14 (22)	29 (19)	22 (31)	175 (24)
None	42 (57)	79 (68)	144 (60)	43 (66)	107 (71)	46 (65)	461 (64)

TEACHER SAFETY TRAINING AND COURSEWORK, CONTINUED

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
District training upon initial hiring	8 (11)	19 (16)	99 (41)	27 (42)	49 (33)	28 (39)	230 (32)
District safety training updates within past five years	35 (47)	45 (38)	151 (63)	36 (55)	86 (57)	46 (65)	399 (56)
Comprehensive training	8 (11)	18 (15)	70 (29)	14 (22)	41 (27)	23 (32)	174 (24)

Note. Comprehensive training = At least one undergraduate or graduate course that discussed safety topics, district training for the teacher upon initial hiring, and safety training update(s) after hiring (within the prior five years provided by district or outside organization.

Summary: Approximately 33% and 64% of participants did not receive any form of safety training in their undergraduate or graduate coursework respectively. A higher percentage of educators from the middle Atlantic region (70%) reported receiving safety training in both undergraduate teaching methods courses and technical courses. The south central region had a high percentage (59%) of educators who had never received any form of safety training in their undergraduate coursework. Nationally, only 32% of the respondents had received training from their school district upon initial hiring, and 56% received training updates from their school district within the prior five years. This is potentially a very dangerous situation for employees (and the students they supervise) tasked with overseeing or having exposure to potential hazards and resulting risks without the appropriate safety training. It could potentially also be deemed negligent, if not reckless, on the part of the employer (school district administration). OSHA's Occupational Exposures to Hazardous Chemicals in Laboratories or Laboratory Standard (29 CFR 1910.1450) and Hazard Communication Standard (29 CFR 1910.1200), along with additional specific OSHA legal standards require employers (school districts) to train employees (educators) upon initial hiring, when there are changes in work assignments, and when there are changes in

Clarifying OSHA's Authority in Schools

Federal OSHA standards and recommendations apply to all private schools. Public schools must comply with either OSHA state approved programs, or federal OSHA standards in states that have adopted OSHA standards by reference. In some states (e.g., Pennsylvania) public schools must comply with the legal safety standards created by the state's Department of Labor and Industry or another state department entity. However, in all cases, private and public schools can both be expected to follow better professional safety practices and potentially be held legally responsible. Educators should check with their state's Department of Education to determine which legal safety standards and better professional safety practices they are required to follow.

safety plans and workplace safety hazards/risks[49]. Please see the box titled *Clarifying OSHA's Authority in Schools* for more details.

There are a number of better professional safety practices supported by professional educational associations and peer-reviewed research that also recommend appropriate safety training of new employees and periodically updated safety training[4,6]. Furthermore, the statistical analyses conducted from this study found comprehensive safety training to be significantly correlated with lower accident rates. Please see the Statistical Analyses (pg. 96) section of this book and the other resulting research publications[42,50] for more details about this significant correlation.

Photo Credit: Penn State Harrisburg, Sharon Siegfried.

SCHOOL DISTRICT SAFETY TRAINING CONTENT FOR TEACHERS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Federal or state OSHA regulations	28 (80)	28 (62)	111 (74)	27 (75)	64 (74)	35 (76)	293 (73)
District's Hazard Communication Plan	26 (74)	28 (62)	91 (60)	28 (78)	59 (69)	24 (52)	256 (64)
SDS	27 (77)	38 (84)	103 (68)	23 (64)	68 (79)	29 (63)	288 (72)
Reading Chemical/ GHS labels	22 (63)	27 (60)	68 (45)	22 (61)	50 (58)	21 (46)	210 (53)
Proper storage and disposal of chemicals, paints, and solvents	20 (57)	24 (53)	89 (59)	23 (64)	60 (70)	28 (61)	244 (61)
First-aid procedures	25 (71)	34 (76)	120 (80)	31 (86)	64 (74)	32 (70)	306 (77)
Addressing unsafe behavioral issues	22 (63)	20 (44)	95 (63)	28 (78)	39 (45)	28 (61)	232 (58)

Note. Only teachers that received district training within the prior five years were included in this table, n = 399.

Summary: Participants indicated a number of important safety topic areas received limited attention during training from their school district: OSHA regulations (73%), hazard communication (HazCom) plan (64%), SDS (72%), chemical storage and disposal (61%), first-aid procedures (77%), and unsafe behavioral issues (58%). In the Greatest Perceived Causes of Accidents table presented later in this book, participants reported student behavioral related issues as one of the top causes of accidents. This suggests that it would be valuable for STEM and CTE educator safety trainings to place a greater emphasis on managing unsafe student behaviors. The lack of coverage of the aforementioned topics places teachers and their students potentially in harm's way relative to safety hazards and resulting risks during hands-on teaching and learning experiences. Better professional safety practices from professional education associations and legal safety standards (OSHA's Occupational Exposures to Hazardous Chemicals in Laboratories or Laboratory Standard 29 CFR 1910.1450, Hazard Communication Standard 29 CFR 1910.1200, and additional specific OSHA legal standards), require employers (school districts) to train employees (educators) on specific safety content and topics. OSHA's *Training Requirements in OSHA Standards* resource provides valuable information about specific content that should be included in trainings based on the standard area (e.g. general industry would encompass STEM education and CTE). Furthermore, studies have explored the content and format that is most effective in STEM education and CTE safety training[4,6].

OTHER SAFETY TRAINING SOURCES FOR TEACHERS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Local source (not school district)	9 (43)	4 (21)	10 (25)	4 (31)	9 (39)	5 (36)	41 (32)
State Teacher Association	4 (19)	6 (32)	6 (15)	2 (15)	5 (22)	0 (0)	23 (18)
State's Department of Education	1 (5)	1 (5)	3 (8)	2 (15)	1 (4)	1 (7)	9 (7)
National Teacher Association	1 (5)	2 (11)	2 (5)	0 (0)	0 (0)	0 (0)	5 (4)
University	0 (0)	1 (5)	13 (33)	0 (0)	0 (0)	2 (14)	16 (12)
OSHA	6 (29)	2 (11)	2 (5)	1 (8)	7 (30)	5 (36)	23 (18)
Manufacturer, curriculum provider, or National Trades Organization	0 (0)	0 (0)	1 (3)	3 (23)	1 (4)	1 (7)	6 (5)
National Safety Training Company (e.g. Flinn Scientific)	0 (0)	3 (16)	3 (8)	1 (8)	0 (0)	0 (0)	7 (5)

Note. Only teachers that received training from someone other than their district within the prior five years were included in this table, n = 130.

Summary: Section 5 (Duties) under OSHA's General Duty Clause states, "Each employer shall furnish to each of his/her employees' employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his/her employees." Additionally, OSHA standards like the Occupational Exposures to Hazardous Chemicals in Laboratories/Laboratory Standard (29 CFR 1910.1450) and the Hazard Communication Standard (29 CFR 1910.1200) require specific training at defined times for employees who have potential hazard exposures. Additionally, in part (b) the General Duty Clause states that, "Each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to this Act which are applicable to his/her own actions and conduct." As licensed professionals, teachers should ensure they receive the proper safety training required by their employers (school district). In addition to local district training, teachers can obtain appropriate training from sources outside of the district as indicated in this study. A number of participants noted their safety training was obtained through local non-school district sources (32%), a state teachers association (18%), a university (12%), or OSHA (18%). The lack of required safety training programs provided by school districts for their educators, and the low percentage of participants who received training from non-school district sources demonstrates a need for universities, professional educator associations, and state education departments to offer more of these required safety trainings. In addition, OSHA as well as state labor and education departments should carefully monitor the required safety training programs provided by school districts to their employees.

SAFETY PRACTICES REQUIRED OF STUDENTS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Always collect signed safety acknowledgement form*	50 (68)	77 (66)	175 (73)	35 (54)	105 (70)	52 (73)	494 (69)
Always secure long hair*	62 (84)	94 (80)	186 (78)	40 (62)	124 (82)	55 (78)	561 (78)
Always secure baggy clothing and remove loose jewelry*	59 (80)	88 (75)	181 (75)	39 (60)	125 (83)	54 (76)	546 (76)
Always wear closed-toe shoes in the lab*	50 (68)	76 (65)	163 (68)	40 (62)	116 (77)	49 (69)	494 (69)
Always wear safety glasses when working with solids and indirectly vented safety goggles when working with hazardous liquids**	35 (47)	38 (33)	110 (46)	27 (42)	61 (40)	26 (37)	297 (41)

Note. * = Prior to any activities being conducted; ** = ANSI/ISEA Z87.1 D3 rated with side shields on safety glasses

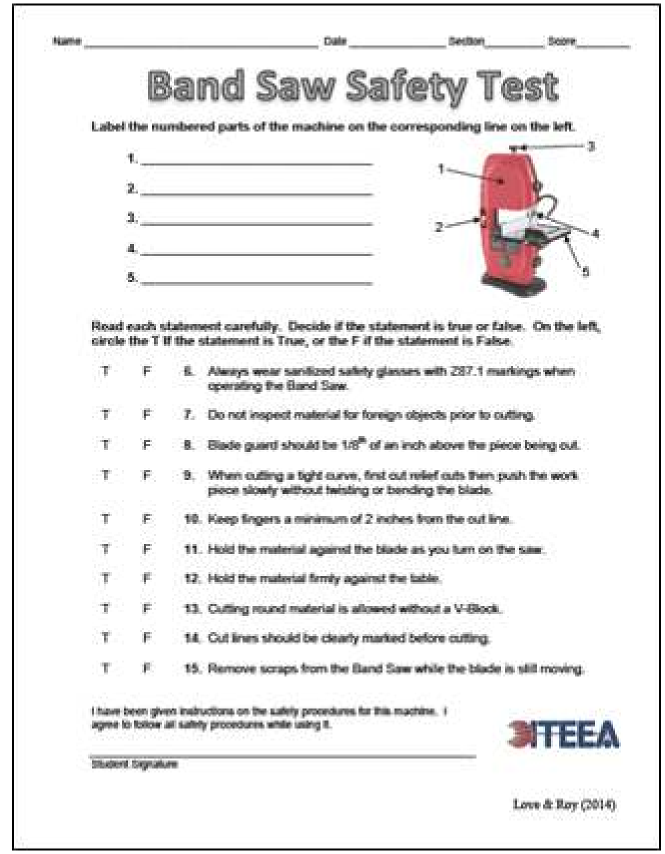
Summary: A critical component of student and teacher safety in STEM and CTE courses revolves around student safety training, expectations, and practices. This portion of the survey exposed some alarming concerns that school districts, administrators, educators, teacher preparation programs, and state education departments would be wise to address. There was a high percentage of teachers who indicated that they do not always require a signed safety acknowledgement form (69%), securing long hair (78%), securing baggy clothing and removing loose jewelry (76%), wearing closed-toe shoes (69%), and the use of appropriate eye PPE (41%). STEM and CTE educators should require each of these practices prior to any lab activities being conducted. Many states have statutes that mandate the use of PPE such as eye protection for any occupant in a room where potentially hazardous activities are being conducted. Additional emphasis needs to be placed on these critical student safety practices to provide a safer learning environment for students and instructors. Deck and Roy[51] provides useful information about requirements for safety glasses with side shields and indirectly vented safety goggles, and Roy[52] describes the importance and limitations of safety acknowledgement forms. ITEEA[53], NSTA[54], and Roy and Love[55] all provide examples of classroom-ready safety acknowledgement forms for educators at all grade levels teaching STEM and CTE content.

SAFETY TESTING FOR STUDENTS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Always complete safety tests for each item*	48 (65)	90 (77)	189 (79)	38 (59)	127 (84)	51 (72)	543 (76)
Must always demonstrate a new procedure while directly supervised	50 (68)	95 (81)	198 (83)	39 (60)	113 (75)	53 (75)	548 (76)
Course quizzes and exams regularly include safety questions?	34 (46)	60 (51)	126 (53)	20 (31)	94 (62)	37 (52)	371 (52)
Always provided with both written and oral safety precautions prior to activity	39 (53)	76 (65)	163 (68)	34 (52)	107 (71)	43 (61)	462 (64)

Note. * = Prior to any activities being conducted.

Summary: In unison with required student safety practices is safety testing. This is paramount for safer hands-on teaching and learning, and is just one critical component of the legal paper trail that educators must document as evidence of fulfilling their duty of care[9,55,56]. As explained by Roy and Love[55], safety testing must be more than just a once and done phenomena that only occurs at the beginning of the year. Effective strategies for keeping safety awareness and assessment on the radar include sample safety questions on all tests and quizzes, and brief safety reviews prior to doing hands-on activities in each class. The responses from participants indicate that greater attention is needed in this area. The lack of student safety testing required before conducting a hazardous activity or using a hazardous item (only required by 76%) was especially alarming. Additionally, the lack of follow-up assessments via safety questions on quizzes and tests (52%) was also an area in need of attention. Furthermore, the percentage of participants who reported providing students with both written and oral safety precautions prior to an activity (64%) is concerning, especially regarding safety instruction for students with disabilities who can benefit from multiple modes of instruction. Collectively these safety testing factors can increase students' cognitive and affective domains related to safety, helping to reduce accidents[10].



Name ____________ Date ________ Section ______ Score ______

Band Saw Safety Test

Label the numbered parts of the machine on the corresponding line on the left.

1. ____________
2. ____________
3. ____________
4. ____________
5. ____________

Read each statement carefully. Decide if the statement is true or false. On the left, circle the T if the statement is True, or the F if the statement is False.

T F 6. Always wear sanitized safety glasses with Z87.1 markings when operating the Band Saw.

T F 7. Do not inspect material for foreign objects prior to cutting.

T F 8. Blade guard should be 1/8th of an inch above the piece being cut.

T F 9. When cutting a tight curve, first cut relief cuts then push the work piece slowly without twisting or bending the blade.

T F 10. Keep fingers a minimum of 2 inches from the cut line.

T F 11. Hold the material against the blade as you turn on the saw.

T F 12. Hold the material firmly against the table.

T F 13. Cutting round material is allowed without a V-Block.

T F 14. Cut lines should be clearly marked before cutting.

T F 15. Remove scraps from the Band Saw while the blade is still moving.

I have been given instructions on the safety procedures for this machine. I agree to follow all safety procedures while using it.

ITEEA

____
Student Signature

Love & Roy (2014)

Example of a safety test from the ITEEA website[53]

SAFETY TESTS AND POSTERS USED

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
ITEEA	5 (7)	11 (9)	41 (17)	2 (3)	8 (5)	6 (9)	73 (10)
Virginia Tech	0 (0)	0 (0)	8 (3)	0 (0)	1 (1)	1 (1)	10 (1)
Power Tool Institute	2 (3)	2 (2)	7 (3)	1 (2)	6 (4)	0 (0)	18 (3)
School district developed	7 (10)	11 (9)	48 (20)	5 (8)	23 (15)	11 (16)	105 (15)
State developed	0 (0)	9 (8)	3 (1)	5 (8)	6 (4)	6 (9)	29 (4)
Teacher developed	53 (72)	72 (62)	109 (45)	44 (68)	101 (67)	39 (55)	418 (58)
Student developed	2 (3)	2 (2)	6 (3)	0 (0)	0 (0)	0 (0)	10 (1)
Do not use safety tests or posters	5 (7)	10 (9)	18 (8)	8 (12)	6 (4)	8 (11)	55 (8)

Summary: As a follow up to the previous question about student safety testing, educators were asked what safety tests and posters they use. The majority of participants indicated they use self-developed safety tests (58%) or ones created by their school district (15%). A small percentage used tests developed by professional organizations or universities (14%), and an even smaller percentage used tests developed by their state department of education (4%). While some indicated that students helped develop their safety tests and posters, caution must be exercised in using this strategy. The instructor must ensure all safety tests and posters have the required safety information. If an instructor is developing their own safety tests, they should ensure that the test and poster match the safety criteria listed in the manual for that specific machine/equipment. Additionally DeLuca et al.[10] highly recommended that educators include a picture of the exact machine/equipment/tool on a poster so that students can make a direct correlation between the safety guidelines and the safety controls on that specific machine/equipment/tool. One of the most alarming statistics from this question was the percentage of participants (8%) who reported using no safety tests or posters. These are essential components of the legal paper trail that educators must document[9,55,56]. Moreover, professional education associations and state education departments can help educators by providing classroom-ready safety tests and posters that have been vetted by safety specialists. ITEEA[53] and Flinn Scientific[57] provide a list of free safety test and poster providers in addition to the excellent classroom-ready safety resources they have created.

Example of a safety poster from ITEEA's safety website[53].

SCHOOL DISTRICT SAFETY POLICIES AND AUDITS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
District has a policy for PPE							
Yes	31 (42)	40 (34)	153 (64)	32 (49)	74 (49)	36 (51)	366 (51)
No	26 (35)	44 (38)	36 (15)	15 (23)	51 (34)	16 (23)	188 (26)
Unsure	17 (23)	33 (28)	51 (21)	18 (28)	26 (17)	19 (27)	164 (23)
District conducts annual safety audits							
Yes	19 (26)	41 (35)	98 (41)	25 (39)	85 (56)	38 (54)	306 (43)
No	45 (61)	49 (42)	88 (37)	18 (28)	45 (30)	19 (27)	264 (37)
Unsure	10 (14)	27 (23)	54 (23)	22 (34)	21 (14)	14 (20)	148 (21)
Written Safety Policy from:							
T&E/STEM Class	15 (20)	31 (27)	60 (25)	10 (15)	25 (17)	16 (23)	157 (22)
T&E/STEM Department	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	2 (0.3)
School district	2 (3)	8 (7)	2 (1)	7 (11)	4 (3)	5 (7)	28 (4)
Class and Department	21 (28)	31 (27)	42 (18)	6 (9)	47 (31)	5 (7)	152 (21)
Class and District	5 (7)	1 (1)	6 (3)	3 (5)	13 (9)	9 (13)	37 (5)
Department and District	2 (3)	0 (0)	1 (0.4)	0 (0)	0 (0)	0 (0)	3 (0.4)

SCHOOL DISTRICT SAFETY POLICIES AND AUDITS, CONTINUED

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Class, Department, and District	14 (19)	24 (21)	111 (46)	25 (39)	48 (32)	24 (34)	246 (34)
No district, department, or class policies	14 (19)	22 (19)	18 (8)	14 (22)	13 (9)	12 (17)	93 (13)

Summary: School safety policies and audits are critical to maintaining a safer lab or makerspace. The results indicate that teacher and student familiarity with safety policies and supervision of district safety policies and audits must be addressed. In many school districts, this appeared to be a low priority given participants' responses about the uncertainty or lack of a PPE policy (49%) and annual safety audits (58%). Ideally there should be aligned safety policies at the district, department, and class levels. If there are policies at lower levels, instructors should make sure they are consistent with policies at the higher level (e.g., district-wide). Gill et al.[58] described practical strategies for developing consistent and collaborative safety policies across STEM education and CTE departments in consultation with a school district's health and safety officials. Additionally, a number of safety checklists are readily available to assist with conducting safety audits[53,59,60].

AVAILABILITY OF MEDICAL PERSONNEL IN THE SCHOOL BUILDING

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Full time	72 (97)	114 (97)	213 (89)	41 (63)	96 (64)	20 (28)	556 (77)
Part time	1 (1)	3 (3)	23 (10)	17 (26)	34 (23)	21 (30)	99 (14)
On request/ As needed	1 (1)	0 (0)	4 (2)	6 (9)	17 (11)	18 (25)	46 (6)
None in school building	0 (0)	0 (0)	0 (0)	1 (2)	2 (1)	9 (13)	12 (2)
Unsure	0 (0)	0 (0)	0 (0)	0 (0)	2 (1)	3 (4)	5 (1)

Summary: Labs and makerspaces can inherently be unsafe places given the potential biological, chemical, and physical hazards present. In this way, the availability of medical personnel in a school building is critical should an accident occur. Nationally, 77% of participants reported full-time medical personnel were available in their building, with 14% noting part-time access to medical personnel. This statistic should be 100%! The board of education/school district as the employer has a responsibility to protect both employees and students from severe injury and potential death. This includes providing medical personnel who can respond in a timely manner should a severe accident occur. Given the time it takes for medical personnel to respond even if located in the building, it is important that teachers are aware of their school district's policy regarding first-aid procedures and are knowledgeable about lifesaving first-aid practices (e.g., CPR, what to do if a student has a seizure)[61], in addition to basic medical support as described in Chapter 9 of Roy and Love's book[55].

FIRST-AID POLICIES AND PRACTICES

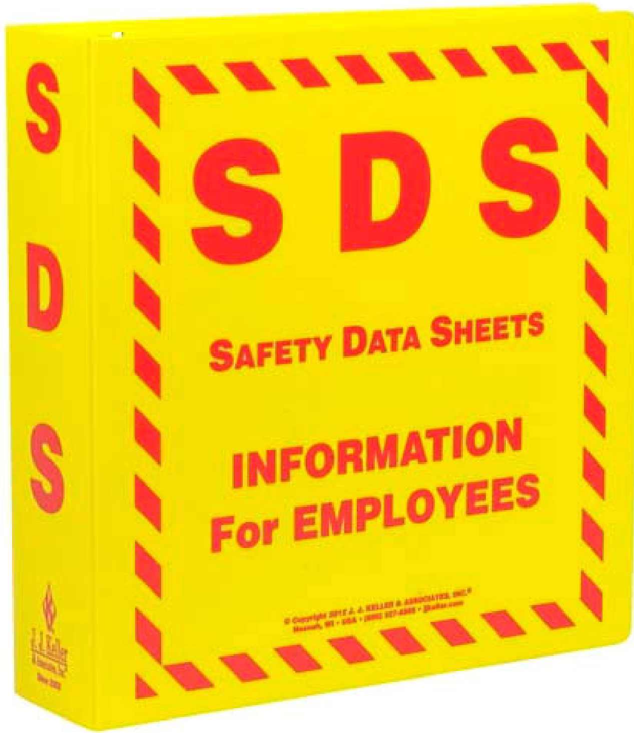
	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Have a fully stocked first-aid kit in the learning area	49 (66)	56 (48)	134 (56)	40 (62)	105 (70)	51 (72)	435 (61)
District re-stocks first aid kit each semester	22 (30)	19 (16)	38 (16)	16 (25)	29 (19)	17 (24)	141 (20)

Summary: Despite 61% of participants reporting their school district provides a first-aid kit for their learning area, only 20% of the districts re-stocked them. This could be dangerous in the event that an accident occurs and first-aid items are needed to provide some level of care until medical personnel arrive (e.g., gloves and sterile gauze to apply pressure to an area that is bleeding). Some school districts do not want educators administering any type of first aid and their policy requires teachers to call the school nurse for all medical needs. However, in some states such as Michigan, teachers are required to receive CPR and first-aid training to obtain their initial teacher licensure. It is important for teachers to understand their school district's policy regarding first-aid safety and also be aware of some basic lifesaving first-aid practices[61] as described in Chapter 9 of Roy and Love's book[55].

COPIES OF SAFETY DATA SHEETS (SDS)

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
T&E/STEM Department							
Yes	40 (54)	66 (56)	96 (40)	23 (35)	92 (61)	38 (54)	355 (49)
No	19 (26)	35 (30)	89 (37)	19 (29)	43 (29)	16 (23)	221 (31)
Unsure	15 (20)	16 (14)	55 (23)	23 (35)	16 (11)	17 (24)	142 (20)
School Nurse							
Yes	22 (30)	32 (27)	39 (16)	13 (20)	29 (19)	9 (13)	144 (20)
No	25 (34)	32 (27)	78 (33)	19 (29)	52 (34)	30 (42)	236 (33)
Unsure	27 (37)	53 (45)	123 (51)	33 (51)	70 (46)	32 (45)	338 (47)
District Facilities Office/Safety Director							
Yes	26 (35)	56 (48)	66 (28)	17 (26)	59 (39)	13 (18)	237 (33)
No	21 (28)	20 (17)	47 (20)	12 (19)	33 (22)	24 (34)	157 (22)
Unsure	27 (37)	41 (35)	127 (53)	36 (55)	59 (39)	34 (48)	324 (45)

Summary: Overall the data indicates there was a lack of SDS copies kept on file by the department, school nurse, and district facilities office/safety director. All three should have copies of SDS for any hazardous materials and chemicals in a classroom, lab, or makerspace[55]. SDSs are required for items as simple as glue or hydrogen peroxide. The high number of teachers that were unsure if their school district's facilities office/safety director had a copy of SDS is alarming. School districts should be communicating with teachers in STEM and CTE programs about providing copies of all SDSs to the district facilities office/safety director, school nurse, and having them readily accessible in the classroom, lab, or makerspace. Additionally, the local fire marshal's office should also receive copies of SDSs for hazardous chemicals used in labs and makerspaces. OSHA's Hazard Communication Standard (29 CFR 1010.1200) requires that employers ensure the SDSs are readily accessible to employees for all hazardous chem-



icals and materials in their workplace. Furthermore, section 1910.1200(h)(1) states that "employers shall provide employees with effective information and training on hazardous chemicals in their work area at the time of their initial assignment, and whenever a new chemical hazard the employees have not previously been trained about is introduced into their work area. Information and training may be designed to cover categories of hazards (e.g., flammability, carcinogenicity) or specific chemicals. Chemical-specific information must always be available through labels and safety data sheets."

For more information about SDSs (how long to keep them on file, etc.) and reading GHS chemical labels, please see Dr. Ken Roy's NSTA safety blog[54] and Flinn Scientific's *Science Lab & Prep Area Safety Guidance Resource*, which was developed in collaboration with the Council of State Science Supervisors[62].

CHEMICAL INVENTORY AND DISPOSAL

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
District Per-forms Annual Inventory							
Yes	32 (43)	64 (55)	76 (32)	25 (39)	71 (47)	23 (32)	291 (41)
No	15 (20)	25 (21)	71 (30)	15 (23)	41 (27)	21 (30)	188 (26)
Unsure	27 (37)	28 (24)	93 (39)	25 (39)	39 (26)	27 (38)	239 (33)
Disposal							
Hazardous waste con-tractor	18 (24)	43 (37)	33 (14)	10 (15)	68 (45)	17 (24)	189 (26)
"Green" disposal methods	0 (0)	0 (0)	5 (2)	2 (3)	2 (1)	1 (1)	10 (1)
Contract through a municipality	13 (18)	15 (13)	17 (7)	6 (9)	22 (15)	8 (11)	81 (11)
Informal disposal (drain/trash)	2 (3)	9 (8)	17 (7)	0 (0)	13 (9)	5 (7)	46 (6)
Do not use hazardous biologicals or chemicals	15 (20)	11 (9)	58 (24)	22 (34)	8 (5)	14 (20)	128 (18)

CHEMICAL INVENTORY AND DISPOSAL, CONTINUED

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Unsure how my district disposes of chemicals	26 (35)	39 (33)	110 (46)	25 (39)	38 (25)	26 (37)	264 (37)

Summary: OSHA standards such as the Occupational Exposures to Hazardous Chemicals in Laboratories, also referred to as Laboratory Standard 29 CFR 1910.1450, and the Hazard Communication Standard (29 CFR 1910.1200) require school districts keep chemical inventories for all hazardous chemicals in their buildings. Inventories are critical for knowing what chemical hazards exist in each lab or makerspace, how old they are, where they are stored, how much of them there are, and other pertinent information. In this study, only 41% of participants knew if their district had a chemical inventory. This information is critical not only for the safety of the students and instructor, but also for other occupants in the building.

Equally alarming is the fact that 37% of participants were unsure how their district disposes of hazardous chemicals. This is a major concern unless the SDS specifies that chemical can safely be poured down the drain. These results serve as an excellent reminder that educators and school districts need to exercise caution before accepting or purchasing any chemicals since they become their responsibility to dispose of properly. Chemical disposal should also be performed as an annual hazardous waste activity. Storage of large amounts of hazardous chemicals can be dangerous and create additional accident risks. Unused chemicals also occupy valuable storage space.

HOUSEKEEPING EFFORTS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Poor	3 (4)	4 (3)	10 (4)	1 (2)	5 (3)	2 (3)	25 (4)
Fair	19 (26)	26 (22)	49 (20)	16 (25)	28 (19)	14 (20)	152 (21)
Good	42 (57)	59 (50)	107 (45)	35 (54)	83 (55)	39 (55)	365 (51)
Excellent	10 (14)	28 (24)	74 (31)	13 (20)	35 (23)	16 (23)	176 (25)

Note. Teachers self-rated their housekeeping efforts.

Summary: Many teachers rated themselves as doing a good or excellent job keeping their lab clean and accessible (76%). This is important for a number of reasons. The first being that, in the event of an accident, teachers must ensure that all occupants can safely evacuate or access engineering controls like master power switches and electrical breaker panels. This is enforced by the NFPA 101 Life Safety Code – Means of Egress/Exits. Additionally, a minimum three foot clearance is required by the Americans with Disabilities Act (ADA) regulations[34,47]. Good housekeeping is also a preventative measure, helping to reduce the chance of an accident occurring (e.g., ensure the floor is clean of wood dust or liquids that could cause slip/fall hazards). This is required under the OSHA general industry housekeeping "Walking-Working Surfaces Standard Number: 1910.22". Lastly, housekeeping habits can be used to demonstrate an instructor's efforts to provide a safer learning environment. In the event of a lawsuit, observed housekeeping practices could be used as part of the testimony. For more information and tips about housekeeping practices please see the articles by Love and Roy[45] and Walls and Strimel[63].

Example of poor housekeeping practices.

FACILITY TYPE AND SQUARE FOOTAGE

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Facility Type							
Portable	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	2 (.05)
Classroom	7 (10)	19 (16)	53 (22)	23(35)	7 (5)	10 (14)	119 (17)
Classroom/ Lab Hybrid	52 (70)	69 (59)	157 (65)	36 (55)	112 (74)	48 (68)	474 (66)
Lab	10 (14)	22 (19)	21 (9)	4 (6)	25 (17)	7 (10)	89 (12)
Maker-space	3 (4)	4 (3)	5 (2)	0 (0)	1 (1)	3 (4)	16 (2)
Floated	1 (1)	3 (3)	4 (2)	2 (3)	6 (4)	2 (3)	18 (3)
Square Footage							
<600	6 (8)	11 (9)	21 (9)	10 (15)	4 (3)	2 (3)	54 (8)
600-800	20 (27)	17 (15)	54 (23)	17 (26)	19 (13)	13 (18)	140 (20)
800-1000	20 (27)	29 (25)	63 (26)	19 (29)	32 (21)	12 (17)	175 (24)
1000-1200	12 (16)	23 (20)	57 (24)	7 (11)	45 (30)	16 (23)	160 (22)
>1200	16 (22)	37 (32)	45 (19)	12 (19)	51 (34)	28 (39)	189 (26)

Note. Facility size listed in square feet.

Summary: The majority of participants (66%) reported having a facility that served as a hybrid classroom and lab. The south central region had a higher percentage (35%) of standard classrooms used for STEM activities while the middle Atlantic (19%) and Midwest (17%) regions had a higher percentage of dedicated lab spaces. The type of facility has important implications for safety. According to the NFPA 101 Life Safety Code, facilities that are classrooms only require 20 square feet per occupant. If lab activities are being performed in a room (including a hybrid classroom/lab model), that space requires 50 square feet per occupant as mandated for school lab and shop facilities according to NFPA 101[24]. In addition to work space, classroom and hybrid designs can also raise concerns about engineering controls (fume hood, master shut-off switches, etc.). This can be especially challenging if planning to convert a traditional classroom or media center/library area into a makerspace, Fab Lab, or STEM lab. All of these criteria and more have to be taken into consideration[55,64].

In regard to square footage the middle Atlantic (32%) and Midwest (34%) regions had a high percentage of facilities over 1,200 square feet. This is positive considering they had the highest percentage of dedicated lab facilities, which can require more space. The west region had the highest percentage of facilities over 1,200 square feet. When examining the square footage it is also important to examine this data in conjunction with the reported course enrollment data presented earlier in this book. These data are compared in the next table.

SQUARE FOOTAGE AND CLASS OCCUPANCY COMPARISONS

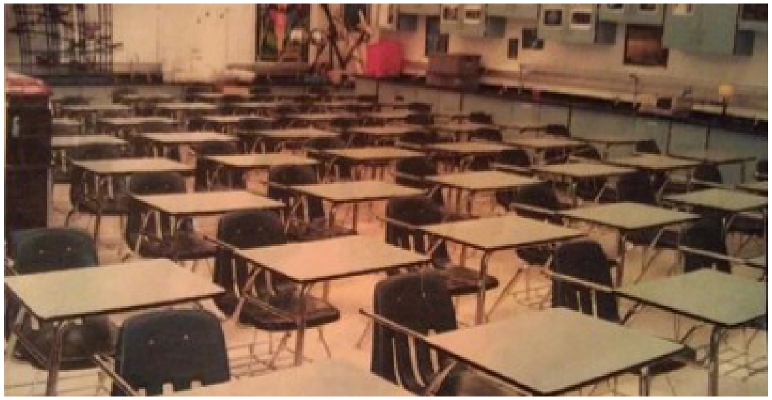
	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Avg. Class Enrollment							
16-20	29 (39)	54 (46)	72 (30)	27 (42)	47 (31)	9 (13)	238 (33)
21-24	21 (28)	29 (25)	63 (26)	10 (15)	37 (25)	16 (23)	176 (25)
25-30	5 (7)	9 (8)	74 (31)	14 (22)	32 (21)	26 (37)	160 (22)
Largest Class Enrollment							
21-24	21 (28)	34 (29)	45 (19)	8 (12)	39 (26)	8 (11)	155 (22)
25-30	20 (27)	37 (32)	82 (34)	26 (40)	58 (38)	20 (28)	243 (34)
>30	2 (3)	8 (7)	71(30)	15 (23)	31 (21)	39(55)	166 (23)
Square Foot-age (max occupants)*							
<600 (≤12)	6 (8)	11 (9)	21 (9)	10 (15)	4 (3)	2 (3)	54 (8)
600-800 (12-16)	20 (27)	17 (15)	54 (23)	17 (26)	19 (13)	13 (18)	140 (20)
800-1000 (16-20)	20 (27)	29 (25)	63 (26)	19 (29)	32 (21)	12 (17)	175 (24)
1000-1200 (20-24)	12 (16)	23 (20)	57 (24)	7 (11)	45 (30)	16 (23)	160 (22)
>1200 (≥24)	16 (22)	37 (32)	45 (19)	12 (19)	51 (34)	28 (39)	189 (26)

Note. Avg. = average; * = maximum number of occupants based off of the NFPA 101 Life Safety Code requirement of 50 square feet per occupant.

Summary: When analyzing the facility square footages within the context of average class enrollments, the south central and south Atlantic regions did not have enough facilities to host the number of classes they reported with enrollments of 21 or more students according to the NFPA 101 square footage occupancy load calculation (50 square feet per occupant)[24]. When analyzing these statistics in relation to the largest class enrollments, no region had enough facilities to host the number of classes with 24 or more students according to the NFPA 101 square footage calculation.

From a national perspective, 57% of participants indicated their largest class had 25 or more students enrolled. However, only 26% of participants indicated they had a facility large enough (>1,200 square feet) to host 25 or more students.

This is extremely concerning given that results from previous studies found a significant increase in school lab accidents as: 1) square footage dropped below 60 square feet per occupant, and 2) enrollments in lab-based courses increased to 24 students or more per one instructor[21,22]. Those studies highlight an important point that must also be taken into consideration when viewing the data from this study. Although a facility may have enough square footage to allow for hosting more than 24 occupants according to the NFPA 101 Life Safety Code requirements, the research and better professional safety practices clearly advise against this. They demonstrate that when a single instructor is tasked with supervising more than 24 students involved in lab activities, there is a significantly greater chance of an accident occurring. Based on those research findings and the data reported in this study, it is strongly recommended that school districts, administrators, district safety officers, school counselors, and STEM and CTE educators closely reexamine their class occupancy load guidelines. These individuals should work together to ensure no more than 24 students per instructor are enrolled in STEM or CTE lab-based classes which can pose greater potential hazards and resulting risks than other courses.



Example of an overcrowded science classroom.

FACILITY SAFETY FEATURES AND ENGINEERING CONTROLS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West na (%)	National n (%)
Safety zones near equip- ment and hazardous work areas	27 (37)	44 (38)	139 (58)	20 (31)	76 (50)	39 (55)	345 (48)
Non-skid strips and/ or rubber matting near machines	14 (19)	40 (34)	50 (21)	9 (14)	63 (42)	19 (27)	195 (27)
Carpet in lab	6 (8)	13 (11)	22 (9)	6 (9)	11 (7)	26 (37)	84 (12)
Dust collec- tion system connected directly to equipment	51 (69)	76 (65)	141 (59)	18 (28)	130 (86)	43 (61)	459 (64)
Adequate recycled ven- tilation	39 (53)	59 (50)	82 (34)	23 (35)	98 (65)	34 (48)	335 (47)
Sink in class- room or lab	57 (77)	87 (74)	183 (76)	33 (51)	130 (86)	53 (75)	543 (76)

FACILITY SAFETY FEATURES AND ENGINEERING CONTROLS, CONTINUED

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West na (%)	National n (%)
Sufficient number of wall GFCI outlets or retractable ceiling outlets	51 (69)	79 (68)	146 (61)	24 (37)	97 (64)	44 (62)	441 (61)
Within the past year, circuit breakers or GFCI outlets tripped while using equipment	13 (18)	29 (25)	67 (28)	8 (12)	62 (41)	25 (35)	204 (28)
Master power cut offs for electric, power, or water	60 (81)	86 (74)	137 (57)	26 (40)	92 (61)	34 (48)	435 (61)
Spill clean-up kit for chemicals and paints	10 (14)	13 (11)	25 (10)	15 (23)	20 (13)	16 (23)	99 (14)
Fire Extinguisher*	67 (91)	101 (86)	192 (80)	52 (80)	145 (96)	58 (82)	615 (86)
Fire Blanket*	33 (45)	35 (30)	42 (18)	17 (26)	57 (38)	13 (18)	197 (27)

Note. * = Within 25 feet of hazardous area.

Summary: OSHA considers engineering controls as the preferred/primary method for dealing with potential laboratory safety hazards and resulting risks. These controls remove or reduce exposure to a chemical or physical hazard by using or substituting engineered machinery, equipment, or safety guards. For example, dust collection systems are critical given wood and metal dust can be carcinogenic and combustible when at elevated particulate levels resulting from power tools like belt/disc sanders. Additionally, metallic dust is a heterogeneous substance with respiratory sensitizing properties. Long-term exposure to metallic dust can affect lung function, creating the possibility for acute or chronic respiratory diseases. In this study only 64% of participants reported having a dust collection system connected directly to equipment, while 47% reported having adequate recycled ventilation. Approximately 61%

had master power cut-off switches for electric, power, or water lines. Twenty-seven percent had fire blankets and 86% had a fire extinguisher. Every space where lab-based activities are occurring must have an appropriate and properly working fire extinguisher! It is also unsafe to operate most power tools and equipment when more than the machine operator is close to the machine; however, only 48% of participants indicated they had safety zones on the floor near equipment/machines and hazardous work areas, and only 27% had non-skid strips near equipment to reduce slip/fall hazards. In the event of a chemical spill, only 14% of respondents had a spill clean-up kit for chemicals, paints, and solvents. Additionally, only 76% participants had a sink in their facility to aid with cleanup, sanitization, and minor accidents. Twelve percent of the respondents had carpet in their facility, which requires extensive cleaning to remove dust particulates and can be hazardous if chemicals are spilled. Lastly, only 61% of participants believe they had a sufficient number of wall GFCI (ground-fault circuit interrupter) outlets or retractable ceiling outlets. Electrical hazards and potential electrocution risks are at a higher frequency in labs than standard classrooms; therefore, GFCI-protected electrical receptacles should be installed and used. In this study, 28% of participants reported that an electrical breaker or GFCI outlet tripped while using a piece of equipment within the lab that year. While one may view this as a negative occurrence, it is actually a positive from the standpoint that it demonstrates the breaker or GFCI outlet worked properly and prevented serious harm. This further illustrates why electrical breakers, GFCI outlets, master power cut-off switches, and other engineering controls should be safely tested at least once a year during a thorough lab inspection. The main takeaway from this data is that, due to the lack of facility safety features and engineering controls reported, these items need immediate attention as soon as possible to help reduce or eliminate major safety hazards. As described in greater detail in the Statistical Analyses (pg. 96) section of this book, resulting studies[42,50] have found many of the aforementioned factors significantly correlated with reducing the number of reported accidents in labs and makerspaces. This further demonstrates the critical importance of facility safety features and engineering controls.

Roy and Love[55] highlight a number of resources that can help school districts and educators address the lack of safety features and engineering controls mentioned in this section. Below is a sample of additional resources found in the references section:

- Safety inspection checklists[53,59,60]
- Fire extinguisher standards[65]
- GFCI outlets[66,67]
- Safety zones and nonskid strip recommendations[68-70]
- Ventilation and wood dust standards[71,72]

EYEWASH STATIONS AND SAFETY SHOWERS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Have an eye-wash station*	64 (86)	77 (66)	145 (60)	34 (52)	121 (80)	58 (82)	499 (69)
Portable*	19 (26)	27 (23)	55 (23)	11 (17)	28 (19)	18 (25)	158 (22)
Plumbed*	45 (61	50 (43)	90 (38)	23 (35)	93 (62)	40 (56)	341 (48)
Flush plumbed eye-wash week-ly**	23 (51)	13 (26)	22 (24)	8 (35)	45 (48)	17 (43)	128 (38)
Plumbed Safety Show-er*	30 (41)	20 (17)	22 (9)	16 (25)	27 (18)	13 (18)	128 (18)

Note. * = Within a 10 second access of hazardous areas; ** = percentages calculated based on the total number of teachers who indicated they had a plumbed eyewash (n = 341).

Summary: There was an alarming lack of eyewash stations (31%) and an unbelievable lack of safety showers (82%) in areas where students were working around chemical and other safety hazards. A higher percentage of schools in the New England, Midwest, and west regions had some form of eyewash station within 10-second access of the area where STEM or CTE activities (involving chemical and other potential safety hazards) were being conducted. Additionally, these regions were more cognizant about flushing their plumbed eyewash weekly despite the very low national average (38%). Plumbed eyewash stations (48%) were more popular than portable stations (22%) in this study. However, the lack of any form of eyewash station in 30% of the facilities is alarming. Eyewash stations are a critical engineering control in STEM and CTE areas to help prevent serious eye injury, including blindness. Even in elementary classrooms that are conducting STEM activities, at a minimum, portable eyewash bottles are needed in the event that a student gets dirt or a hazardous liquid (e.g., vinegar) in their eye[55,73].

Example of an eyewash station that was not kept clear of debris nor tested weekly.

The OSHA requirements that serve as a legal standard for emergency eyewashes and showers (29 CFR 1910.151(c)) specify that "where the eyes or body of any person may be exposed to injurious corrosive materials, suitable facilities for quick drenching or flushing of the eyes and body shall be provided within the work area for immediate emergency use."

In addition, as a better professional practice, the current ANSI/ISEA standard addressing emergency eyewash and shower equipment (ANSI/ISEA Z358.1-2014) calls for eyewash and shower equipment in appropriate situations when employees are exposed to hazardous materials. The ANSI/ISEA standard also requires all eyewashes and showers to deliver an appropriate amount of tepid water between 60°F (16°C) and 100°F (38°C) per minute for a minimum of 15 minutes in a required pattern. Finally, per the ANSI/ISEA Z358.1-2014 Standard, emergency showers and eyewashes are required to be activated weekly, with a more thorough evaluation on an annual basis.

For more information about eyewash stations and safety showers please read Love and Roy's[74] article.

Safety Note: Photo shows young student working with liquids and having only eye protection (i.e., safety goggles) for personal protective equipment (PPE). Potential hazardous liquids warrant additional PPE for hands (e.g., nitrile gloves) and body (e.g., non-latex apron or lab coat). Also liquid containers need to be labeled.

TELEPHONE ACCESS FROM LAB AREA

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
< 25 feet	59 (80)	75 (64)	161 (67)	38 (59)	86 (57)	38 (54)	457 (64)
25-50 feet	13 (18)	30 (26)	52 (22)	11 (17)	40 (27)	15 (21)	161 (22)
51-75 feet	0 (0)	8 (7)	10 (4)	4 (6)	15 (10)	7 (10)	44 (6)
76-100 feet	0 (0)	2 (2)	4 (2)	2 (3)	4 (3)	3 (4)	15 (2)
> 100	0 (0)	0 (0)	1 (0.4)	0 (0)	3 (2)	4 (6)	8 (1)
No school phone in classroom or lab area	2 (74)	2 (2)	12 (5)	10 (15)	3 (2)	4 (6)	33 (5)

Summary: Approximately 64% percent of participants reported having telephone access within 25 feet of their lab area, and 22% had access within 25-50 feet. OSHA's employee alarm systems standard 1910.165(b)(4) requires, "the employer shall explain to each employee the preferred means of reporting emergencies, such as manual pull box alarms, public address systems, radio, or telephones. The employer shall post emergency telephone numbers near telephones, or employee notice boards, and other conspicuous locations when telephones serve as a means of reporting emergencies." If telephone is the school district's designated method for reporting emergencies in a lab, there needs to be an easily accessible phone in the lab. As Roy and Love[55] describe, the instructor should post directions for using the phone and a list of emergency numbers next to the phone so that a student can make the emergency call in the event that an instructor is unable.

SOLDERING

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Use soldering equipment in their lab	42 (57)	65 (56)	128 (53)	25 (39)	80 (53)	36 (51)	376 (52)
Have an externally vented fume hood for soldering activities	4 (10)	9 (14)	12 (9)	5 (20)	18 (23)	7 (19)	55 (15)
Have portable soldering fume extractors	3 (7)	8 (12)	13 (10)	4 (16)	9 (11)	8 (22)	45 (12)

Note. Only teachers who indicated they facilitate soldering activities in their classes were included in this table.

Summary: Soldering can expose occupants in a room to hazardous chemical vapors, hence non-lead-based solder should be used whenever possible. The lack of fume extraction used by participants is concerning. Only 27% of respondents noted having portable soldering fume extractors or externally vented fume hoods. Portable fume extractors are relatively affordable and should be secured in place and operational during soldering activities. Love and Tomlinson's[75] article describes safer practices for soldering, including clean-up procedures. Additionally, ITEEA[53] has developed a soldering safety poster and test.

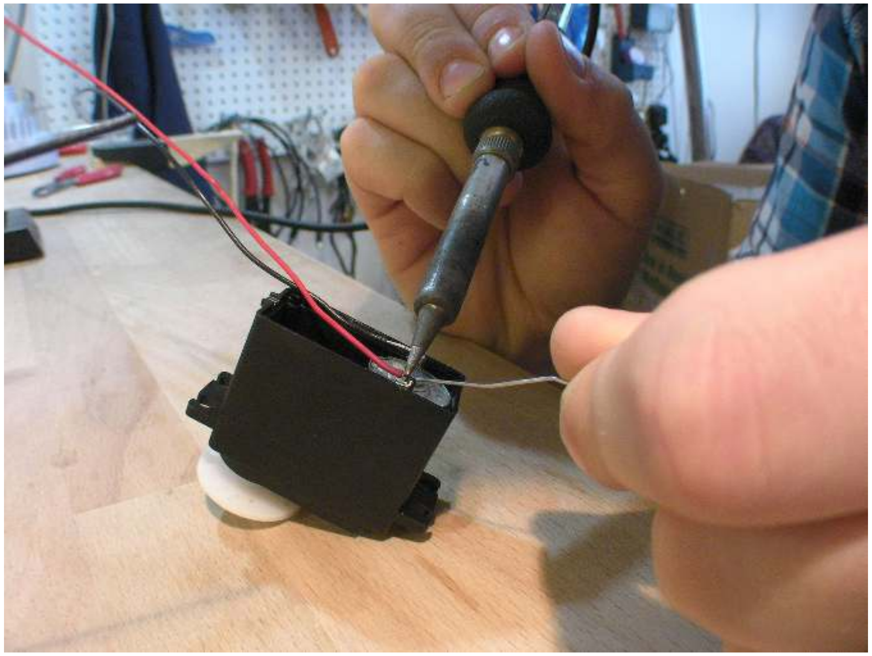


Photo Credit: Soldering wires to the motor by Bekathwia. CC BY-SA 2.0.

TABLE SAW USAGE

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Have a table saw in their lab	44 (60)	78 (67)	157 (65)	24 (37)	127 (84)	39 (55)	469 (65)
Have a Saw-Stop table saw	28 (64)	39 (50)	58 (37)	9 (38)	95 (75)	35 (90)	264 (56)
Usage policy							
Instructor only	17 (39)	29 (37)	79 (50)	8 (33)	18 (14)	9 (23)	169 (34)
Student use with direct supervision*	17 (39)	23 (30)	54 (34)	9 (38)	30 (24)	11 (28)	144 (31)
Students can use independently with instructor in lab area*	10 (23)	26 (33)	24 (15)	7 (29)	79 (62)	19 (49)	165 (35)

Note. Only teachers who indicated they had a table saw were included in this table; * = Use only allowed after passing safety tests

Summary: SawStop has reported that on average 65,000 Americans suffer from a table saw accident each year, with a single amputation costing schools and businesses a minimum of $130,000. When the operation of a machine or accidental contact with a machine poses an injury risk to the operator or others in the vicinity, the potential hazards must be eliminated or controlled. OSHA's machine guarding standard 1917.151 requires adequate and appropriately functioning machine guarding to protect machine operators and others in the vicinity. This usually involves the guard specified by the machine manufacturer. Table saws are a prime example of the need for machine guarding and direct supervision given some of the horrific accidents that have occurred at secondary education level[8]. As a result of these potential hazards and serious bodily risks, student table saw use must be carefully monitored via direct supervision under duty or standard of care[76].

In this study 65% of educators indicated they have a table saw in their lab. The Midwest had a much higher percentage of labs with a table saw in comparison to other regions. This is not surprising given the Midwest also reported teaching a higher percentage of courses with a manufacturing focus as presented in Appendix A (pg. 111).

Approximately 35% of participants reported allowing their students' to use the table saw independently with an instructor in the room. Upon further analysis, the authors examined what percentage of educators had a SawStop table saw among the 165 who allowed independent student use. It was discovered that 35 (21%) of those who were allowing independent student use did not have a SawStop table saw. Even with the SawStop technology, direct supervision should still be provided given the high risks associated with a table saw in comparison to other equipment in a lab. Student maturity, cognitive ability, psychomotor ability, behavioral record, experience with high hazards equipment, and other factors must be considered when deciding whether to allow a student to operate a table saw after training and testing. Instructors should first check with their state department of education and school district to determine if there is a policy on student table saw usage. A previous study[42] found SawStops were significantly correlated with reduced accident occurrences in comparison to table saws without the SawStop technology. **Based on these findings it is *strongly recommended* that school districts invest in a SawStop table saw if they wish to allow capable students to use a table saw under direct supervision.** One other important note, if a school has both SawStop and non-SawStop table saws in their building, it is better legal practice to limit student use exclusively to the SawStop machine while being directly supervised.

A high school senior in an upper level manufacturing class using a push stick to rip a piece of stock on a SawStop table saw.

WELDING, CASTING, OR MOLDING

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Use welding, casting, or molding equipment in your lab?	21 (28)	25 (21)	27 (11)	9 (14)	74 (49)	19 (27)	175 (24)
Approved face protection for all students conducting these types of activities?	20 (95)	23 (92)	24 (89)	8 (89)	72 (97)	17 (90)	164 (94)
Approved PPE for all students doing these types of activities?	20 (95)	21 (84)	22 (82)	8 (89)	67 (91)	17 (90)	155 (89)
Have an externally vented fume hood for welding activities	15 (71)	17 (68)	18 (67)	4 (44)	68 (92)	17 (90)	139 (79)
Have welding booths with appropriate protection	17 (81)	18 (72)	18 (67)	6 (67)	67 (91)	16 (84)	142 (81)

Note. Only teachers who indicated they conducted welding, casting, and molding activities in their courses were included in this table.

Summary: Approximately 24% of participants indicated their students conducted welding, casting, or molding activities in their lab or makerspace. The Midwest had a much higher percentage of educators conducting these activities than other regions. There was a concerning lack of approved PPE (including eye/face protection) for all students conducting these types of activities in the lab. Moreover, the lack of welding booths and welding ventilation may be a result of participants facilitating casting and molding activities as opposed to welding. Regardless, adequate ventilation and other safety measures must be taken for hot metal work. This also applies to plasma-cutting activities, encompassing both handheld and CNC plasma-cutting operations, which require special safety considerations. Hypertherm, Inc.[77] provides excellent plasma-cutting safety resources for both students and instructors. More information about welding, casting, and molding safety is described by Roy and Love[55] or can be found in OSHA's 1910 Subpart Q – Welding, Cutting, and Brazing standard.

3D PRINTERS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Have a 3D printer in their lab	59 (80)	95 (81)	172 (72)	47 (72)	109 (72)	57 (80)	539 (75)
Built-in HEPA filter	8 (14)	11 (12)	30 (17)	13 (28)	26 (24)	3 (5)	91 (17)
Used inside of an exter-nally vented fume hood	2 (3)	1 (1)	4 (2)	2 (4)	3 (3)	1 (2)	13 (2)
Used near an electrostatic air filter	5 (9)	7 (7)	9 (5)	1 (2)	4 (4)	5 (9)	31 (6)
Do not have any form of ventilation for the 3D printer	44 (75)	76 (80)	129 (75)	31 (66)	76 (70)	48 (84)	404 (75)

Note. Only teachers who indicated they had a 3D printer were included in this table.

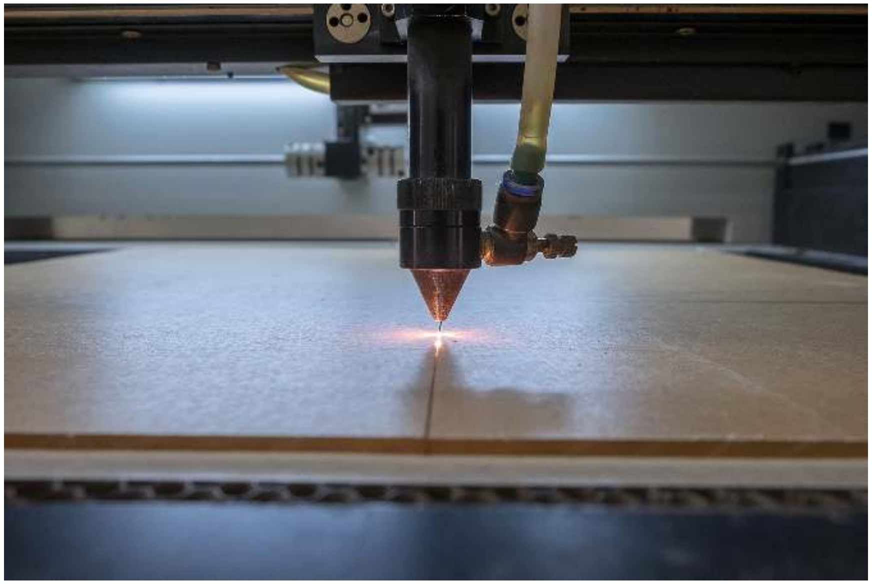
Summary: Emerging research has found that desktop 3D printers can produce hazardous levels of ultrafine particles (UFPs)[78,79]. Of grave concern was the fact that a large percentage of participants (75%) indicated they were not using any form of ventilation when operating their 3D printer(s). **It is *strongly recommended* that school districts purchase the appropriate ventilation for spaces with 3D printers and develop a policy on this matter in collaboration with their health and safety office.** Carnegie Mellon University[80] provides an excellent example of a 3D-printing ventilation policy.

LASER ENGRAVERS/CUTTERS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Have a laser engraver in their lab	25 (34)	67 (57)	86 (36)	21 (32)	82 (54)	37 (52)	318 (44)
Internal exhaust and cooling unit	10 (40)	9 (13)	41 (48)	3 (14)	30 (37)	6 (16)	99 (31)
Externally vented ex-haust	15 (60)	56 (84)	36 (42)	16 (76)	51 (62)	29 (78)	203 (64)
Do not have any form of ventilation for the laser engraver	0 (0)	2 (3)	9 (11)	2 (10)	1 (1)	2 (5)	16 (5)

Note. Only teachers who indicated they had a laser engraver were included in this table.

Summary: Approximately 44% of participants indicated they have a laser engraver/cutter. Venting the exhaust externally was more common than an internal exhaust system that can be costly to maintain. One area of concern—5% of participants reported having no means of ventilation. Laser engravers/cutters can produce extremely hazardous fumes. Educators should follow the manufacturer's recommendations for adequate ventilation. Additional resources have provided recommendations for safer laser engraver/cutter operation[55,81].



FINISHING ROOM AND/OR CHEMICAL STORAGE AREAS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Facility has a lockable flammables cabinet	48 (65)	85 (73)	147 (61)	34 (52)	121 (80)	43 (61)	478 (67)
Facility has a finishing room or chemical storage area	21 (28)	70 (60)	81 (34)	24 (37)	101 (67)	31 (44)	328 (46)
Finishing room or chemical storage area is separate from other storage, the lab, or class-room	17 (81)	56 (80)	64 (79)	20 (83)	90 (89)	25 (81)	272 (83)
Finishing room or chemical storage area can be locked	20 (95)	60 (86)	73 (90)	23 (96)	88 (87)	25 (81)	289 (88)

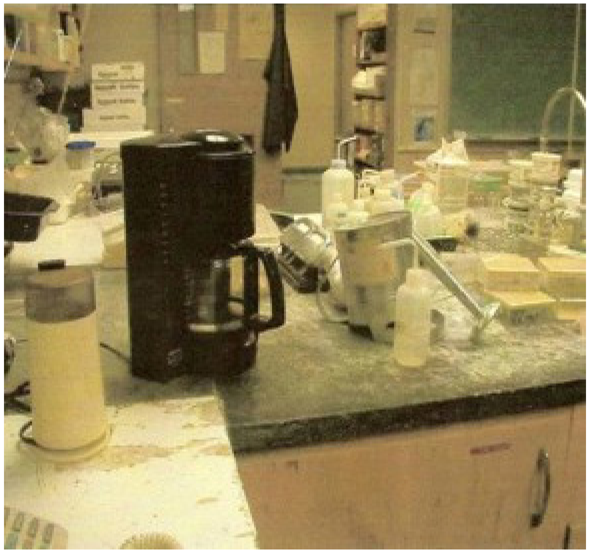
FINISHING ROOM AND/OR CHEMICAL STORAGE AREAS, CONTINUED

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Chemicals are stored by compatible groups	14 (67)	49 (70)	49 (61)	22 (92)	63 (62)	15 (48)	212 (65)
Finishing room or chemical storage area has an externally vented paint booth or chemical fume hood	15 (71)	56 (80)	48 (59)	11 (46)	81 (80)	26 (84)	237 (72)

Note. Only teachers who indicated they had a finishing room or chemical storage area were included in this table.

Summary: OSHA and NFPA require chemical storage areas to be secured to prevent access by unauthorized occupants. Some participants (12%) reported that their finishing room or chemical storage area could not be locked. If a student gains access to this area and sustains injuries (on site or off site) as a result of their access, the teacher and school district would ultimately be liable. Participants (28%) also reported a lack of externally vented paint booths in their finishing room and chemical fume hoods in their chemical storage area. This creates potential exposure to hazardous fumes, particulates, etc. with resulting health and safety risks. These risks can be reduced with paint booths or chemical fume hoods. Without these essential engineering controls in place, educators should not have students conducting any finishing work which requires the use of potentially hazardous chemicals!

Improper storage of incompatible items.



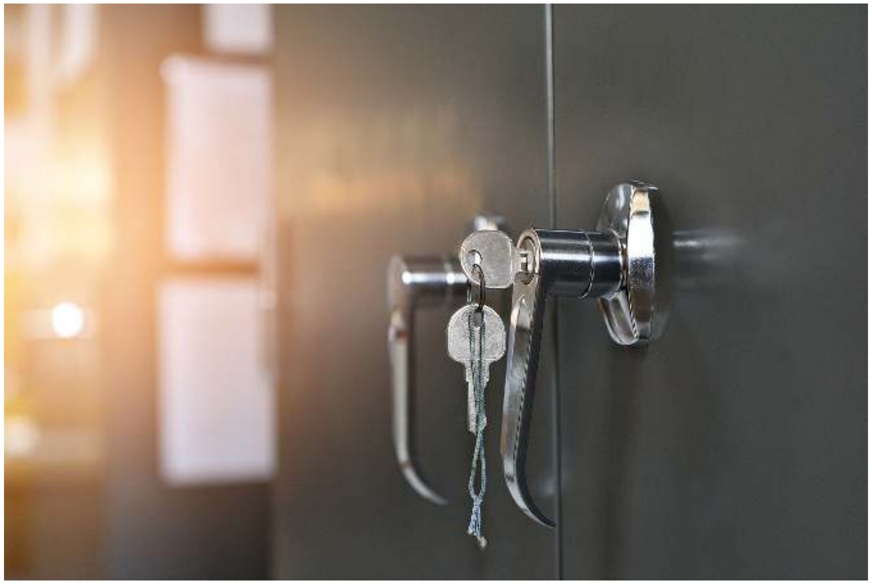
Additionally, only 65% of respondents noted chemicals are stored by compatible groups. This is a very dangerous statistic! Teachers should be receiving training from their school district regarding proper chemical storage, including information that can be obtained from Section 7 of a Safety Data Sheet (SDS). As required by OSHA 29 CFR 1910.1200, a SDS must be easily accessible to employees for every hazardous chemical in the workplace. It is absolutely critical to have proper storage and handling of hazardous chemicals to reduce or eliminate some of the associated risks.

Poor housekeeping, clean-up, and storage in addition to cross contamination hazards with food and drink items.

STUDENT ACCESS TO NON-CHEMICAL STORAGE AREAS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Believe they have sufficient project, material, and equipment storage	45 (61)	66 (56)	158 (66)	40 (62)	88 (58)	41 (58)	438 (61)
Have lockable tool/storage cabinets	60 (81)	97 (83)	197 (82)	43 (66)	114 (76)	46 (65)	557 (78)
Access to Storage Areas							
No student access	12 (16)	23 (20)	93 (39)	24 (37)	19 (13)	18 (25)	189 (26)
Occasional T&E student access	45 (61)	65 (56)	115 (48)	28 (43)	93 (62)	30 (42)	376 (52)
Occasional non-T&E student access	1 (1)	4 (3)	1 (0.4)	2 (3)	5 (3)	3 (4)	16 (2)
Occasional access for any students	7 (10)	12 (10)	18 (8)	3 (5)	26 (17)	13 (18)	79 (11)
Do not have a storage area	9 (12)	13 (11)	13 (5)	8 (12)	8 (5)	7 (10)	58 (8)

Summary: Inadequate storage and/or teacher office space is frequently cited by educators as one of the top limitations related to their lab or makerspace[55]. This study reaffirmed this concern as only 61% of participants believed they had sufficient storage space. Of greatest concern from this data was the high percentage of facilities with non-lockable storage cabinets (22%) and access to storage areas for students not in the class (13%). If a student needs access to a storage area to store or retrieve projects, obtain tools, etc. they should be closely supervised by an instructor. Under duty or standard of care, students should not be allowed access to storage areas where there are potentially hazardous items (e.g., hand tools) and that pose resulting risks.



The risks associated with allowing students to access storage areas can be seen in *Kush v. City of Buffalo*[82]. In this case a school was found negligent for not securing hazardous chemicals and not locking its chemical storage area. Students snuck into the chemical storage room and stole chemicals that resulted in second-degree burns to the students. Since the chemical storage area was left unlocked, this was determined to be a breach of duty that a reasonable prudent person could have foreseen as harmful. The court ruled that not locking the chemical storage room and breaching their duty to supervise students allowed the accident to occur. The school district was deemed negligent.

PERSONAL PROTECTIVE EQUIPMENT (PPE) AVAILABLE

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Have safety glasses for each student working with solids*	67 (91)	96 (82)	192 (80)	47 (72)	137 (91)	54 (76)	593 (83)
Have safety goggles for each student working with liquids**	34 (46)	47 (40)	113 (47)	36 (55)	59 (39)	33 (47)	322 (45)
Have safety glasses or goggles cabinet with UV light	47 (64)	67 (57)	148 (62)	24 (37)	46 (31)	27 (38)	359 (50)
Have non-latex aprons for each student	29 (39)	51 (44)	87 (36)	23 (35)	59 (39)	30 (42)	279 (39)
Have appropriate types of gloves for each student	43 (58)	69 (59)	102 (43)	31 (48)	107 (71)	42 (59)	394 (55)
Have appropriate ear protection for each student in areas with loud equipment	46 (62)	54 (46)	94 (39	22 (34)	99 (66)	36 (51)	351 (49)

Note. * = with side shields and ANSI/ISEA Z87.1 D3 rated; ** = Indirectly vented and Z87.1 D3 rated.

Summary: OSHA's Personal Protective Equipment Standard (29 CFR 1910.132) applies to STEM and CTE teachers as employees. Either state PPE statutes for students or better professional safety practices by professional education associations apply to students. In this study only 45% of participants reported having indirectly vented safety goggles for each student working with liquids, and 83% had safety glasses for all students working with solids. Also, not all respondents had appropriate types of gloves (55%) or ear protection (49%) for each student. Given legal safety standards and better professional safety practices, no student or teacher should be allowed in a space where lab activities are occurring without first wearing the appropriate PPE. There is shared liability for the teacher and administration should an accident occur in which a resulting injury could have been avoided or been less severe with the proper use of PPE. The data reveals an alarmingly high percentage of educators do not have basic PPE required for all occupants in a lab. Statistical analyses found safety glasses with side shields, gloves, and aprons for each student to be significantly correlated with lower accident occurrences[42]. **School districts have a legal duty to ensure STEM and CTE classes have the appropriate PPE, and they should address all PPE shortcomings in their district immediately.** Unfortunately, teachers who know there are PPE shortcomings but still allow hazardous activities to take place put themselves in legal jeopardy should a student get injured. Lastly, only 50% of participants indicated they have an ultraviolet (UV) sanitizing cabinet for glasses and goggles. Although this is nice to have, Deck and Roy[51] describes other methods that can be used to sanitize safety glasses and goggles. Chapter 4 of Roy and Love's book[55] provides more details about required PPE for various activities.

SCHOOL DISTRICT LITIGATION AND INJURY RECORDS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Litigation							
Yes	2 (3)	12 (10)	10 (4)	0 (0)	15 (10)	12 (17)	51 (7)
No	55 (74)	84 (72)	113 (47)	46 (71)	113 (75)	33 (47)	444 (62)
Unsure	17 (23)	21 (18)	117 (49)	19 (29)	23 (15)	26 (37)	223 (31)
Records							
Yes	50 (68)	86 (74)	151 (63)	47 (72)	122 (81)	48 (68)	504 (70)
No	5 (7)	5 (4)	8 (3)	3 (5)	4 (3)	2 (3)	27 (4)
Unsure	19 (26)	26 (22)	81 (34)	15 (23)	25 (17)	21 (30)	187 (26)

Note. The litigation question asked teachers if their school had been involved in a lab accident lawsuit or settlement during their employment at the school. The second question asked if their school district kept records of injuries that occurred within the past year.

Summary: Litigation and injury records go hand-in-hand. If a student gets injured while taking part in a STEM or CTE activity, the teacher and school district have potential shared liability for their failure to prevent the harm to the student. This is based on the teacher and school district's responsibility under "duty or standard of care." The duty or standard of care is a legal obligation requiring that a teacher/supervisor/administrator observe a standard of reasonable care when acting or engaging in conduct that could potentially harm students or other employees[76].

If there is a lab or makerspace accident, the teacher and/or supervisor/administrator may be charged with negligence or even worse, recklessness involving deliberate indifference. The main difference between negligence and recklessness is that negligence has a lesser level of liability (the state of being legally responsible for something). Negligence simply involves acting in a careless manner, while recklessness involves a person taking a risk while knowing their actions may cause harm to another[55]. It is critical that in the event of an accident, teachers carefully complete a lab accident report provided by their school district using the recommendations provided by Love and Roy[83]. Should a lawsuit develop out of a lab or makerspace injury, the accident report will be subpoenaed. It is also recommended that the instructor take timestamped photos of the area where the accident

occurred and retain copies to verify what safety measures were in place at the time of the accident (safety posters, safety zones on floor, guard in place and operational, etc.).

Although only 7% of participants reported being involved in a lab or makerspace accident lawsuit during their employment, it can be a stressful experience involving fines, loss of employment, and even imprisonment. Love[8,9] emphasizes the importance of creating a legal paper trail and presents examples of relevant court rulings which have helped inform educators' safety knowledge[4,6]. The NSTA blog post titled, *Reducing the Risk of Liability in the Lab* provides details that can help teachers and supervisors/administrators address issues concerning duty of care and specific safety actions that can be taken to reduce one's liability in a classroom/lab/makerspace[84].

INCIDENT AND ACCIDENT OCCURRENCES WITHIN ONE YEAR

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Incidents							
0	27 (37)	39 (33)	89 (37)	35 (54)	54 (36)	30 (42)	274 (38)
1-10	45 (61)	76 (65)	145 (60)	30 (46)	90 (60)	41 (58)	427 (60)
11-20	1 (1)	2 (2)	6 (3)	0 (0)	6 (4)	0 (0)	15 (2)
>30	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	2 (0.3)
Minor Accidents							
0	16 (22)	13 (11)	58 (24)	24 (37)	15 (10)	18 (25)	144 (20)
1-5	42 (57)	74 (63)	149 (62)	35 (54)	102 (68)	46 (65)	448 (62)
6-10	12 (16)	21 (18)	25 (10)	6 (9)	22 (15)	4 (6)	90 (13)
11-15	2 (3)	4 (3)	5 (2)	0 (0)	6 (4)	1 (1)	18 (3)
>15	2 (3)	5 (4)	3 (1)	0 (0)	6 (4)	2 (3)	18 (3)
Major Accidents							
0	66 (89)	106 (91)	217 (90)	60 (92)	120 (80)	65 (92)	634 (88)
1-5	8 (11)	11 (9)	23 (10)	5 (8)	31 (21)	6 (9)	84 (12)

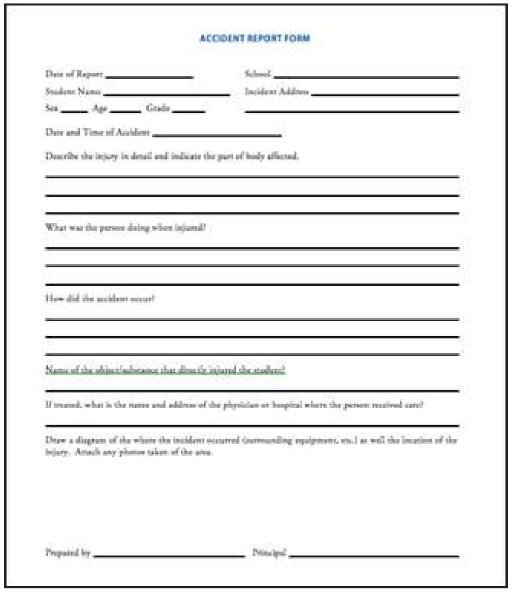
Note. Minor accidents[21] included water or chemical spills, slipping on dusty floors, broken glass, excessive fumes, small fires, projectiles, etc., during activities in the classroom, lab, or field that did not involve injury to anyone. Minor medical attention[21] included Band-Aids, minor first aid, or a visit to the nurse. A major accident[21] was defined as an injury to someone that did require major medical attention with a visit to a doctor or hospital.

ACCIDENT OCCURRENCES WITHIN 5 YEARS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Minor Accidents							
0	11 (15)	10 (9)	46 (19)	23 (35)	6 (4)	14 (20)	110 (15)
1-10	29 (39)	53 (45)	124 (52)	30 (46)	74 (49)	40 (56)	350 (49)
11-20	15 (20)	23 (20)	43 (18)	8 (12)	35 (23)	9 (13)	133 (19)
21-30	13 (18)	19 (16)	13 (5)	3 (5)	19 (13)	5 (7)	72 (10)
>30	6 (8)	12 (10)	14 (6)	1 (2)	17 (11)	3 (4)	53 (7)
Major Accidents							
0	51 (69)	75 (64)	184 (77)	52 (80)	83 (55)	48 (68)	493 (69)
1-10	22 (30)	42 (36)	55 (23)	13 (20)	68 (45)	23 (32)	223 (31)
11-20	1 (1)	0 (0)	1 (0.4)	0 (0)	0 (0)	0 (0)	2 (0.3)

Note. Minor accidents[21] included water or chemical spills, slipping on dusty floors, broken glass, excessive fumes, small fires, projectiles, etc., during activities in the classroom, lab, or field that did not involve injury to anyone. Minor medical attention[21] included Band-Aids, minor first aid, or a visit to the nurse. A major accident[21] was defined as an injury to someone that did require major medical attention with a visit to a doctor or hospital.

Summary: Labs and makerspaces are inherently dangerous places given the amalgam of biological, chemical, and physical hazards present. Participants' responses reflected this in that 80% had one or more minor accidents that year, 12% had one or more major accidents that year, 36% had 11 or more minor accidents within the prior five years, and 31% had one or more major accidents within the prior five years. The key take-away from this is that not all accidents can be foreseen or avoided, especially as the percentage of hands-on teaching and learning time increases. However, facility design, PPE, engineering controls, standard operating procedures, and other safety factors can help to reduce the likelihood and severity of an accident. Additionally, student and instructor safety training before doing any hands-on laboratory work at the beginning of the school year and before each activity is essential to help reduce accidents[4,6,42,50].



ACCIDENT REPORT FORM

Date of Report ________ School ________

Student Name ________ Incident Address ________

Sex ____ Age ____ Grade ____

Date and Time of Accident ________

Describe the injury in detail and indicate the part of body affected.

What was the person doing when injured?

How did the accident occur?

Name of the object/substance that directly injured the student?

If treated, what is the name and address of the physician or hospital where the person received care?

Draw a diagram of the where the incident occurred (surrounding equipment, etc.) as well the location of the injury. Attach any photos taken of the area.

Prepared by ________ Principal ________

Example of an accident report form[53].

EVACUATION DUE TO FUMES

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Occurred to teacher during demonstration of lab prep	9 (18)	12 (17)	23 (17)	4 (14)	19 (17)	3 (8)	70 (16)

Note. Only includes participants who indicated they teach welding, casting, molding, or soldering activities (n = 435).

Summary: Approximately 16% of participants indicated they had to evacuate their facility due to fumes that year. Only teachers that reported conducting soldering or welding/casting/molding activities were included in this analysis. It should be noted that wood dust, chemicals, and other items not associated with soldering or metalworking can be combustible and result in hazardous fumes. NFPA 45 requires labs to have ongoing ventilation with 100% fresh air which is not recycled to other parts of the building[71]. This is to prevent the spread of noxious fumes, particulate matter, flammable vapors, carcinogens, etc. It also reduces occupant exposure to these airborne safety hazards and resulting risks. In addition, when working with highly concentrated airborne safety hazards, spray booths and/or fume hoods are required. Like the ventilation systems, these also require preventative maintenance to ensure the engineering controls work as designed. All of these engineering controls help to prevent fires and the need for evacuation due to fumes or other airborne safety hazards. They also reduce the health risks for repeated exposure to carcinogens, mutagens and reproductive toxins found in finishing chemicals, paints, solvents, stains, etc. This is most important for teachers as they spend more time in the facility throughout the year in comparison to their students who are usually only there for a portion of the day.

MOST COMMONLY INJURED PERSONS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Teacher	22 (30)	39 (33)	60 (25)	11 (17)	43 (29)	22 (31)	197 (27)
Student	53 (72)	94 (80)	179 (75)	42 (65)	134 (89)	52 (73)	554 (77)
Guest	0 (0)	3 (3)	5 (2)	2 (3)	5 (3)	1 (1)	16 (2)
Occurred to teacher during demonstration or lab prep	5 (7)	11 (9)	12 (5)	4 (6)	10 (7)	6 (9)	48 (7)

Note. Teachers could select multiple choices, hence the sum of percentages for each category is greater than 100%

Summary: The majority of safety incidents/accidents occurred to students (77%) with a smaller percentage involving the teacher during instruction (27%) or a lab prep (7%). There were even a small percentage of incidents/accidents that occurred to guests. This number of accidents to persons other than the teacher or students reiterates the need for PPE by everyone who enters a space where hazardous activities are being conducted. Accidents during teacher demonstrations or prep time also highlight the need for wearing appropriate PPE and following proper safety protocols every time there is a potential safety hazard and resulting risk. In most instances, when dealing with active flames or hazardous chemicals, safety shields or fume hoods/spray booths, in addition to appropriate PPE must be used to protect observers and the operator. For physical safety hazards, eye/face protection, hand protection, and other PPE are required, along with appropriate distancing to better protect observers and the operator.

GREATEST PERCEIVED CAUSES OF ACCIDENTS

		New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Student failure to follow safety protocols	1st	41 (55)	75 (64)	147 (61)	33 (51)	100 (66)	48 (68)	444 (62)
	2nd	12 (16)	19 (16)	35 (15)	14 (22)	21 (14)	7 (10)	108 (15)
	3rd	4 (5)	3 (3)	17 (7)	4 (6)	7 (5)	4 (6)	39 (5)
Overcrowd-ing	1st	16 (22)	27 (23)	54 (23)	17 (26)	32 (21)	12 (17)	158 (22)
	2nd	17 (23)	36 (31)	66 (28)	15 (23)	50 (33)	24 (34)	208 (29)
	3rd	8 (11)	10 (9)	21 (9)	3 (5)	15 (10)	5 (7)	62 (9)
Inadequate facilities or equipment	1st	3 (4)	6 (5)	12 (1)	8 (12)	10 (7)	5 (7)	44 (6)
	2nd	5 (7)	8 (7)	31 (13)	6 (9)	17 (11)	5 (7)	72 (10)
	3rd	16 (22)	20 (17)	35 (15)	11 (17)	20 (13)	6 (8)	108 (15)
Classroom manage-ment	1st	4 (5)	3 (3)	9 (4)	1 (2)	3 (2)	4 (6)	24 (3)
	2nd	14 (19)	12 (10)	34 (14)	3 (5)	14 (9)	9 (13)	86 (12)
	3rd	7 (10)	13 (11)	36 (15)	8 (12)	22 (15)	10 (14)	96 (13)
Percentage of SWD in a course	1st	0 (0)	0 (0)	1 (0.4)	0 (0)	1 (0.6)	0 (0)	2 (0.3)
	2nd	7 (10)	10 (9)	13 (5)	7 (11)	18 (12)	3 (4)	58 (8)
	3rd	9 (12)	19 (16)	24 (10)	4 (6)	17 (11)	6 (9)	79 (11)

Note. Participants ranked their top three perceived causes. The 1st, 2nd, and 3rd rows reflect their 1st, 2nd, and 3rd choices. Overall, only the top five causes are reported here despite other selection options that were available. SWD = Students with disabilities

Summary: Nationally, approximately 62% believed the greatest cause for accidents was student failure to follow safety protocols, while 22% believed it was from overcrowding. However, when asked what the second greatest cause was, overcrowding was the most popular choice (29%). In regard to the third greatest cause, inadequate facilities or equipment (15%), classroom management (13%), and percentage of students with disabilities (SWD) in a course (11%) were among the top perceived reasons for accidents. When looking at the national totals across the first through third choices, the causes rank as the following from greatest to least: (1) Student failure to follow safety protocols, (2) overcrowding, (3) inadequate facilities or equipment, (4) classroom management, and (5) percentage of SWD in a course. When examining the results by region they were fairly consistent across the U.S., however the inadequate facilities or equipment was much more of a top concern in the south central region than other areas. When comparing these results to previous research that examined a similar question focused on CTE programs[11], the results varied. Threeton and Evanoski[11] found that chronic student absences, percentage of SWD in a course, lack of funding, overcrowding, and inadequate facilities were the greatest causes (listed in order with the greatest cause first). While both studies found similar causes, overcrowding was much more of a concern to educators in this study, whereas the percentage of SWD in a course and inadequate facilities were greater concerns in Threeton and Evanoski's study. These findings highlight the importance of these issues, which are necessary to maintain safer instruction in hands-on STEM and CTE instructional areas. School districts and administrators should seek ways to provide support and resources for teachers regarding these areas of concern.

Teachers also need to be aware of students who are repeat offenders of safety protocols, which calls for progressive disciplinary action and potentially safer alternative assignments[46]. In cases of overcrowding and inadequate facilities, the teacher not only puts students at risk but also themselves safety-wise and legally. Teachers with overcrowded classes (a surpassed occupancy load) and/or inadequate facilities should not be doing hands-on activities. In doing so, under duty or standard of care they could be subject to lawsuits if a student gets hurt[76]. Instructors need to inform their supervisors and the administration of any safety issues (in writing) and solicit their assistance. Once corrected, hands-on activities can be resumed. For additional information about working with administrators to address occupancy load issues see West's[25] article and Ken Roy's NSTA safety blog[24], and for concerns about behavioral issues see the articles by Farmer[85] and Gill et al.[58]. For assistance with addressing the number of SWD enrolled in a course please see Love et al.[46].

Example of a student work permit tag to assist with classroom management and safety[85].

MOST COMMON ITEM ATTRIBUTED WITH SAFETY INCIDENTS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Hot glue gun	30 (41)	46 (39)	116 (48)	18 (28)	34 (23)	26 (37)	270 (38)
Broken glass	4 (5)	11(9)	15 (6)	6 (9)	7 (5)	2 (3)	45 (6)
Spills or splashes	17 (23)	21 (18)	20 (8)	11 (17)	21 (14)	16 (23)	106 (15)
Equipment or machinery	15 (20)	35 (30)	41 (17)	6 (9)	50 (33)	17 (24)	164 (23)
Automated equipment	3 (4)	6 (5)	11 (5)	1 (2)	3 (2)	5 (7)	29 (4)
Hand or portable power tools	12 (16)	25 (21)	48 (20)	8 (12)	41 (27)	15 (21)	149 (21)
Fumes	5 (7)	12 (10)	20 (8)	3 (5)	12 (8)	3 (4)	55 (8)
Fires	4 (5)	0 (0)	4 (2)	0 (0)	6 (4)	0 (0)	14 (2)
Projectiles	9 (12)	19 (16)	36 (15)	3 (5)	20 (13)	13 (18)	100 (14)
Electrical short	4 (5)	10 (9)	20 (8)	0 (0)	5 (3)	6 (9)	45 (6)
Outdoor activities	1 (1)	1 (1)	1 (1)	2 (3)	0 (0)	5 (7)	12 (2)

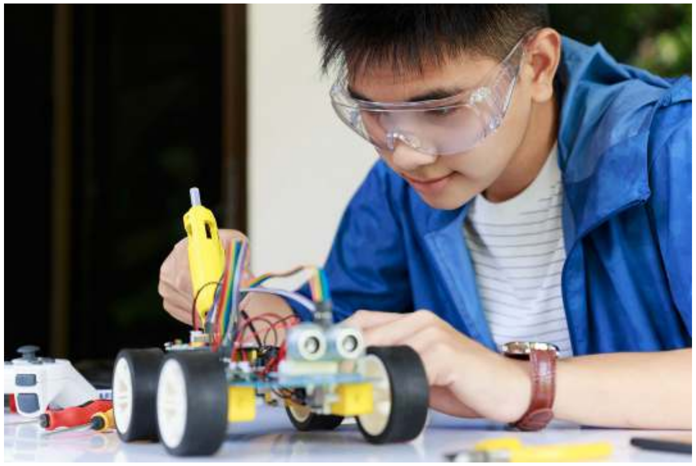
Summary: In order to help prevent or reduce safety incidents it is important to know what items are causing injuries. The top items participants reported as being associated with safety incidents (no medical attention or school nurse visit required) were hot glue guns (38%), followed by equipment or machinery (23%), hand or portable power tools (21%), spills or splashes (15%), and projectiles (14%). Hot glue guns were the number one rated item in all regions except the Midwest where equipment, machinery, and portable power tools were more commonly associated with safety incidents. These items all reiterate the importance of PPE, safety practices, and safety training to prevent safety incidents from becoming more serious injuries.

To address the safety hazards and resulting risks posed by the aforementioned items, teachers need to first conduct a potential safety hazard analysis and resulting risk assessment, then determine the appropriate safety actions to be taken[55,86]. Areas or sources in which there are repeated accidents should require students to have additional safety training and competency testing before resuming activities. The following resources can help address safety concerns with items shown to be linked to safety incidents: Hot glue gun safety[87], spills or splashes[51,55], hand/power tools and machinery/equipment[10,53,55,88], and projectiles[55].

MOST COMMON TOOL/EQUIPMENT ATTRIBUTED WITH ACCIDENTS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Hot glue gun	24 (32)	11 (9)	38 (16)	21 (32)	9 (6)	14 (20)	100 (14)
Hand tools	18 (24)	18 (15)	47 (20)	9 (14)	49 (33)	(20 (28)	161 (22)
Hobby knives and box cut-ters	3 (4)	13 (11)	26 (11)	7 (11)	7 (5)	4 (6)	60 (8)
Sharp mate-rials, splin-ters, project materials	6 (8)	10 (9)	7 (3)	8 (12)	15 (10)	5 (7)	51 (7)
Band saw	4 (5)	10 (9)	7 (3)	3 (5)	13 (9)	3 (4)	40 (6)
Portable power tools	3 (4)	2 (2)	5 (2)	0 (0)	14 (9)	2 (3)	26 (4)
Soldering iron	2 (3)	7 (6)	8 (3)	4 (6)	1 (1)	3 (4)	25 (4)
Sanders (belt, disc, and oscillating)	1 (1)	4 (3)	2 (1)	1 (2)	6 (4)	1 (1)	15 (2)
Table saw	0 (0)	1 (1)	2 (1)	0 (0)	7 (5)	2 (3)	12 (2)
Manufactur-ing equip-ment - Other	1 (1)	1 (1)	2 (1)	0 (0)	3 (2)	4 (6)	11 (2)
Welding or Handling metals	1 (1)	2 (2)	0 (0)	0 (0)	6 (4)	0 (0)	9 (1)
Drill press	2 (3)	0 (0)	0 (0)	0 (0)	3 (2)	0 (0)	5 (1)

Summary: The hazardous items that participants reported as being most commonly linked to safety accidents (requiring minor or major medical attention) mirrored the responses reported for safety incidents. Hand tools (22%) were associated with more accidents than hot glue guns (14%). Nationally, hobby knives, box cutters, and sharp materials were attributed with a higher percentage of accidents than power tools or any piece of equipment. Band saws (6%) were the machine most frequently attributed with accidents.



As with safety incidents, in order to help prevent or reduce safety accidents, teachers need to first conduct a potential safety hazard analysis, resulting risk assessment, and then determine the appropriate safety actions to be taken[55,86]. Areas or sources in which there are repeated accidents, should require students to have additional safety training and competency testing before resuming activities. The resources mentioned in the previous table summary are helpful for addressing potential safety hazards and resulting risks associated with safety incidents are also applicable here.

MOST COMMON INJURY FROM AN ACCIDENT

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Burns	34 (46)	63 (54)	130 (54)	26 (40)	85 (56)	35 (49)	373 (52)
Ingestion of foreign materials	0 (0)	3 (3)	4 (2)	3 (5)	2 (1)	1 (1)	13 (2)
Electrical shock	0 (0)	4 (3)	10 (4)	1 (2)	3 (2)	3 (4)	21 (3)
Cuts/ Lacerations	57 (77)	94 (80)	182 (76)	38 (59)	142 (94)	56 (79)	569 (79)
Chemicals in eye	2 (3)	4 (3)	5 (2)	3 (5)	6 (4)	6 (9)	26 (4)
Fire	4 (5)	4 (3)	5 (2)	2 (3)	9 (6)	4 (6)	28 (4)
Explosion	1 (1)	1 (1)	1 (0.4)	1 (2)	1 (1)	0 (0)	5 (1)
Fumes	5 (7)	12 (10)	18 (8)	7 (11)	12 (8)	6 (9)	60 (8)
Projectiles	9 (12)	16 (14)	32 (13)	5 (8)	26 (17)	14 (20)	102 (14)
Trip/Fall Hazards	15 (20)	24 (21)	58 (24)	13 (20)	31 (21)	17 (24)	158 (22)
Impalement	0 (0)	2 (2)	1 (0.4)	1 (2)	4 (3)	1 (1)	9 (1)
Amputation	0 (0)	2 (2)	2 (1)	1 (2)	3 (2)	2 (3)	10 (1)
Other	12 (16)	13 (11)	18 (8)	3 (5)	14 (9)	5 (7)	65 (9)

Note. Teachers could select multiple types of injuries that had occurred; therefore, percentages do not total to 100%.

Summary: The most common type of injury reported was a cut or laceration (79%), followed by burns (52%), trip/fall hazards (22%), and projectiles (14%). When examining these types of injuries in relation to the items that were reported as being attributed to safety incidents and accidents one can see potential connections. Cuts and lacerations could be related to hand/power tool and equipment use, sharp materials/splinters, and hobby knives and box cutters. Burns may have resulted from the reported hot glue gun incidents/accidents, and trip/fall safety hazards could be from unattended spills/splashes, extension cords, or poor housekeeping practices. As with safety incidents and accidents, to prevent or reduce safety hazards, teachers need to first conduct a potential safety hazard analysis, resulting risk assessment, and then determine the appropriate safety actions to be taken[55,86]. Areas or sources in which there are repeated accidents should require students to have additional safety training and competency testing before resuming activities. Chapter 9 of Roy and Love's[55] book as well as Dr. Ken Roy's NSTA safety blog[61] provide detailed information on addressing various types of emergencies.

Minor burn on the far right finger.

Extension cords create common trip/fall hazards.

MOST COMMONLY INJURED BODY PART FROM ACCIDENTS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
No incidents	10 (14)	12 (10)	34 (14)	18 (28)	7 (5)	12 (17)	93 (13)
Fingers/ Hands	64 (87)	104 (89)	202 (84)	45 (69)	142 (94)	58 (82)	615 (86)
Eyes/Face	0 (0)	0 (0)	1 (0.4)	0 (0)	1 (1)	1 (1)	3 (0.4)
Arms	0 (0)	0 (0)	1 (0.4)	0 (0)	0 (0)	0 (0)	1 (0.1)
Other body part	0 (0)	1 (1)	2 (1)	2 (3)	1 (1)	0 (0)	6 (1)

Summary: After investigating safety incidents, accidents, types of injuries, and attributed hazards/items, the last factor to examine is which body part is most commonly affected by safety incidents and accidents. Participants indicated the majority of injuries occurred predominantly to fingers or hands. This is consistent with findings from a previous statewide CTE study[89]. The low percentage of injuries to the eyes indicates that PPE such as safety glasses with side shields or goggles may have protected students from serious injuries in this area.

To prevent or reduce injuries to these body parts, teachers need to first conduct a potential safety hazard analysis, resulting risk assessment, and then determine the appropriate safety actions to be taken[55,86]. Areas or sources in which there are repeated accidents should require students to have additional safety training and competency testing before resuming activities. Chapter 9 of Roy and Love's[55] book as well as Dr. Ken Roy's NSTA safety blog[61] provide detailed first-aid information[61].

STATISTICAL ANALYSES

- **Love, T. S., Roy, K. R., & Sirinides, P. (2021). What factors have the greatest impact on safety in Pennsylvania's T&E courses? *Technology and Engineering Education Association of Pennsylvania Journal, 69*(1), 5-22.**
- **Love, T. S., Sirinides, P., & Roy, K. R. (2022). Examining factors associated with accidents in CTE and STEM education labs: A national safety study. *Paper presented at the annual meeting of the American Educational Research Association*, San Diego, CA.**

Love et al.[42] examined the landscape of safety specific to survey participants from Pennsylvania. They also conducted polychoric correlation tests using responses from the full national sample to determine what factors were significantly correlated with accident occurrences. A number of factors were identified as being associated with a significant increase in accidents (contributing factors), or a significant decrease in accidents (reducing factors) (please see tables that follow). Love et al.[50] also presented a more in-depth description of the research methods implemented and the results from the polychoric correlation tests.

Additionally, Love et al.[42] conducted a series of predictive models using logistic regression tests to examine what factors served as significant predictors of accidents. Safety training was found to be a significant predictor. More specifically, this analysis revealed that safety training received from a higher education technical course or T&E/STEM teaching methods course did not significantly decrease the chance of an accident occurring. However, Love et al. found that teachers who received a combination of the following had a 37% lower chance of an accident occurring in their lab: (1) safety training in their higher education technical or methods coursework, (2) from their district when initially hired, and (3) during in-service safety training updates provided by their district or an external source within the five years prior to completing the TEE-FASS survey.

Statistically Significant Factors Correlated with Increased Accident Rates

Contributing Factor	Details
Type of courses taught	E.g., Materials processing compared to CAD or electronics/ programming/robotics classes
>25% of class time spent doing hands-on T&E work	
Type of facility	Hybrid classroom/lab facilities had significantly more accidents than other types of facilities
Table saw use	For those who indicated they have a table saw, there were significantly more accidents reported among those who said they let students use them independently as opposed to those that allowed students to use under direct supervision or only be operated by the instructor

Statistically Significant Factors Correlated with Reduced Accident Rates

Reducing Factor
Safety glasses w/side shields for every student in class
Dust collection system connected directly to equipment
A fire extinguisher within 25 feet of hazardous work areas
Circuit breakers that have been tripped within the past year
Use of GFCI outlets as opposed to non-GFCI outlets
Appropriate gloves available for students when needed
Appropriate aprons for students when needed
A finishing/chemical storage room separate from the lab/classroom
Lockable flammables cabinet
Lockable tool storage cabinets
Master shut off switch for electric, gas, and water
Safety zones designated on the floor near hazardous equipment/machines
Non-skid strips on the floor near hazardous equipment/machines
Type of table saw: SawStop as opposed to a non-SawStop

SUMMARY AND DISCUSSION OF THE FINDINGS

In summary, many findings emerged from this study; however, the following were among some of the most alarming safety statistics that are worth highlighting:

1. A large percentage (52%) of teachers reported having four or more preps per semester, which could place increased safety responsibilities on teachers (e.g., additional set up and maintenance). Previous studies have found more than two preps in a semester to contribute to increases in accidents[43].

2. Related to facilities, there was a noticeable lack of safety zones, access to eye-wash stations and showers, fully stocked first-aid kits, emergency power shut-off controls, ventilation for soldering, and PPE for welding/casting/molding in lab facilities[55].

3. Air filtration is also something that research has indicated districts should invest in for operating 3D printers but were reported absent in this study (75% reported no 3D printer ventilation). Emerging studies have found hazardous levels of ultrafine particles (UFPs) are often emitted from desktop 3D printers[78-80].

4. School nurses, STEM and CTE departments, district safety officers, and the local fire marshal should all have a copy of SDS for hazardous materials/chemicals found in STEM and CTE labs within a school[55,90].

5. A large percentage of teachers noted they did not require a signed safety acknowledgment form, passing of safety tests, use of safety glasses/indirectly vented goggles, securing long hair and loose jewelry/clothing, and wearing of closed-toe shoes before any student was allowed to conduct lab activities. This presents serious legal and safety issues as many state statutes require appropri-

ate eye protection in addition to better professional safety practices, which this study found were not followed consistently or with fidelity[9,51].

6. Only 38% of participants reported testing their eyewash and showers for several minutes every week as called for by the ANSI/ISEA Z358.1-2014 eyewash/shower standard[74].

7. There was an identifiable lack of safety training as only 54% of participants reported receiving such training during undergraduate technical and/or teaching methods courses. This not only puts students at a higher risk of an accident, but also the teacher. Teacher preparation programs and mentor teachers should ensure safety is a core focus for all pre-service teachers.

8. There was also an identifiable lack of safety training provided by school districts. OSHA requires employers (school districts) to train employees (teachers) upon initial hiring, anytime thereafter a new potential safety hazard and resulting risk is present (e.g., new equipment, new chemical, etc.), and when there is a new job assignment in the workplace[49] (STEM or CTE lab). The statistical analyses described earlier in this section revealed that a lack of safety training, along with other factors, were significantly associated with increased accident rates.

SECTION V

RECOMMENDATIONS

RECOMMENDATIONS

The following is a nonexhaustive list of recommendations derived from the data to provide for a safer teaching and learning experience when facilitating STEM and CTE activities in a lab or makerspace:

1. Fire code NFPA 101 Life Safety Code requires 50 square feet per occupant (net square footage) in academic labs and shops. (Research suggests a minimum of 60 square feet limits accident rates[21,23-25]).
2. Work with your district safety compliance officer, chemical hygiene officer, legal counsel, fire marshal, administrators/supervisors, and teachers to develop a mandatory safety program, including safety plans, protocols, inspections, training, supervision, etc.[91]
3. Work with your Board of Education to help develop a school district lab safety policy. Ensure your class, department, and school safety regulations and protocols align with this district-wide policy[58].
4. Refer to legal resources (OSHA[49,88,92], NFPA, etc.) and professional resources (ACTE[37,93], ASEE[94], ITEEA[53], NSTA[54], NSELA[95], ANSI/ISEA, etc.) for additional information in developing a safety program.
5. Enforce safety policies, regulations, and protocols consistently and fairly[58].
6. Safety Training must be administered upon initial hire, again any time new potential safety hazards and resulting risks are introduced (chemical, equipment, etc.), when updates are made in safety plans, and/or when there is a new teaching/job assignment[49].
7. Under duty of care, the employer (school district) has a legal and professional responsibility to provide safety trainings, supervision, and appropriate yet consistent progressive disciplinary actions[76].
8. Employees can and should request in writing that their employer (e.g., school district) provide safety trainings if they are unsure about any safety-related topics, equipment, process, chemical, storage/disposal, etc.[49] Under OSHA Standard 29 CFR 1910.30, employers (e.g., school systems) are required to provide appropriate training for employees (e.g., instructors).
9. At a minimum, conduct an annual safety inspection to make sure your facilities have proper safety engineering controls and work space. ITEEA[53] and the National Institute for Occupational Safety and Health (NIOSH)[59] both have excellent inspection checklists for a variety of STEM and CTE labs. Additionally, NSTA's safety blog titled "The Safety Checklist: Navigating to Safer Waters!"[60] provides examples of essential components for safety checklists.
10. Make sure the instructional space meets all OSHA, NFPA, ANSI/ISEA, and other legal safety standards and better professional practices to make it safer for teachers, students, and observers/visitors[24,34].
11. Flush out emergency eye wash sink/shower stations once a week for one to three minutes[74].
12. Check first-aid kits each semester and work with your school nurse to restock them[55,61].

13. Use a UV goggle sanitizer with a UV-C Germicidal bulb to sanitize eye protection devices after each individual's use[51].

14. Have at least three to seven sinks with running cold and hot water sources in your lab/makerspace based on class enrollment. An adequate number of sinks should be available to facilitate proper and timely hand washing for all students at the end of class[90].

15. Have a separate lockable/secure finishing or chemical storage room and chemical storage cabinet to prevent student access. Chemical and material storage information can be obtained from Section 7 of a Safety Data Sheet (SDS). Additionally, Flinn Scientific[57] offers excellent resources regarding chemical storage (e.g., compatible groups).

16. Have a lockable/secure tool cabinet to prevent student access when not in use.[16,64]

17. All students should be safety trained and tested, and sign a safety acknowledgement form before starting any work involving hazardous equipment, tools, chemicals, and materials.[9,52-55]

18. Have appropriate taped or painted safety work zones on the floor near all machines/equipment. This includes installing non-skid strips near machines/equipment to prevent slip/fall safety hazards. This is especially applicable to manufacturing equipment such as table saws, lathes, sanders, jointers, etc., which emit wood dust and require mobility to properly use the equipment.[68-70]

19. Have appropriate continuously on-going and non-recycled ventilation to accommodate particulate and aerosol hazards.[71,72]

20. Have fume hoods and/or spray booths for activities resulting in the production of high concentrations for fumes, vapors, smoke, etc. Check and replace filters as needed to ensure adequate ventilation.[55,71]

21. Have separate wood and metal dust collection systems with the intake vent placement at the machine source of wood or metal dust production (when possible to do so safely) to prevent exposure to airborne wood or metal dust.[71,72]

22. Have workspace accessible to wheelchair-bound students per ADA requirements. Love et al.[46] described a number of excellent online resources such as the University of Washington's DO-IT (Disabilities, Opportunities, Internetworking, and Technology) Center[48] and the American Chemical Society's book titled, *Teaching Chemistry to Students with Disabilities* (4th edition)[47] which both describe accessibility considerations, accommodations, and modifications in great detail. School systems and educators should work with their facilities director (and architects when designing/renovating spaces) to ensure all current ADA requirements are met, and an adequate number of accessible stations or other accommodations are available based on the needs of the occupants.

23. Have all electrical receptacles GFCI-protected.[66,67]

24. Ensure emergency power shut-off switches and other required engineering controls are easily accessible[96].

25. Have a sufficient number of electrical receptacles to eliminate the use of extension cords on the floor.[67]

SAFETY CONSIDERATIONS FOR DESIGNING A STEM EDUCATION OR CTE FACILITY

With the aforementioned recommendations in mind, the first important component of designing, constructing, and using a STEM or CTE facility is to make sure appropriate legal safety standards (OSHA, NFPA, etc.) and better professional safety practices (ITEEA, NSELA, NSTA, etc.) are addressed. The NSTA Safety Blog titled *The Safety Checklist: Navigating to Safer Waters!*[60] discusses how to address this. As that blog notes, STEM learning spaces can be inherently unsafe places with potential hazards and resulting risks. This is why the development and use of a safety checklist is very valuable. First, the safety checklist functions as a guide to help teachers and their supervisors identify safety issues and make the appropriate plans to address them. Second, the checklist also serves as a legal documentation illustrating an intent to work in a safer teaching/learning environment. Additionally, Roy and Love discuss in detail the planning process and safety considerations for planning and renovating various types of instructional areas within makerspaces, STEM labs, and Fab Labs[55]. School systems should work in concert with architects, designers, safety compliance officers, and others to ensure the design of a facility not only meets safety standards and codes (engineering controls, ADA compliance, etc.), but that it also meets curricular needs and will have the flexibility to meet the needs of the school for multiple decades. The resources and recommendations described in this book can help educators and schools proactively plan for and address myriad safety issues while reducing the potential hazards and resulting risks.

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APPENDIX A

DEMOGRAPHIC RESULTS

PARTICIPANT DEMOGRAPHICS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
Gender							
Male	53 (72)	86 (74)	166 (69)	35 (54)	137 (91)	53 (75)	530 (74)
Female	21 (28)	31 (26)	74 (31)	30 (46)	14 (9)	18 (25)	188 (26)
Race							
White	71 (96)	110 (94)	195 (81)	61 (94)	147 (97)	63 (89)	647 (90)
Hispanic	1 (1)	1 (1)	3 (1)	1 (2)	0 (0)	2 (3)	8 (1)
Black	0 (0)	0 (0)	31 (13)	0 (0)	1 (1)	2 (3)	34 (5)
Asian	0 (0)	0 (0)	4 (2)	0 (0)	0 (0)	0 (0)	4 (0.6)
Middle Eastern	1 (1)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0.3)
Native Hawaiian or Pacific Islander	0 (0)	0 (0)	0 (0)	1 (2)	0 (0)	0 (0)	1 (0.1)
American Indian or Alaska Native	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	1 (0.1)
Two or more races	1 (1)	5 (4)	7 (3)	2 (3)	2 (1)	6 (71)	21 (3)

Summary: The percentage of female teachers in this study (26%) was almost identical to the national average (25%) for T&E educators reported by Ernst and Williams[97] in 2015. The south central region was much more diverse than the national average in terms of gender, whereas the Midwest was the least diverse in both gender and race. The south Atlantic was the most diverse in regard to race. The national statistics for race in this study were also similar to findings from previous research[97]. However, this study had a lower percentage of Hispanic (1), Asian (0.6), and American Indian/Alaska Native (0.1) educators than Ernst and Williams's[97] research, which reported the following statistics: 7% Hispanic, 2% Asian, and 3% American Indian/Alaska Native.

T&E/STEM TEACHING EXPERIENCE

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
0-3 (years)	4 (5)	8 (7)	30 (13)	14 (22)	8 (5)	6 (9)	70 (10)
4-8	7 (10)	20 (17)	59 (25)	18 (28)	18 (12)	20 (28)	142 (20)
9-15	15 (20)	27 (23)	48 (20)	8 (12)	31 (21)	14 (20)	143 (20)
16-25	22 (30)	41 (35)	56 (23)	17 (26)	49 (33)	16 (23)	201 (28)
≥ 26	26 (35)	21 (18)	47 (20)	8 (12)	45 (30)	15 (21)	162 (23)

Summary: Participants were almost equally dispersed among the various teaching experience categories. Beginning teachers (0-3 years) comprised the smallest category while teachers with 16-25 years of experience made up the largest category (28%). Half of the teachers in the south central region had 8 or less years of experience teaching T&E/STEM courses, whereas the New England (65%) and Midwest (63%) regions had a higher percentage of teachers with 16 or more years of T&E/STEM teaching experience.

The results presented in this table have implications for program sustainability as well as safety due to the critical nationwide shortage of highly-qualified STEM and CTE teachers, especially in T&E education[98-100]. Regions with a large percentage of teachers in the ≥26 category may experience higher turnover rates in the upcoming years due to retirements. School districts and state education departments should collaborate with higher education teacher preparation programs to proactively explore strategies that will encourage secondary students and career changers to pursue a career as a STEM or CTE educator. STEM and CTE programs can be made safer through the recruitment, hiring, and retention of highly-qualified candidates that have received adequate safety training through STEM and CTE teacher preparation programs/certification coursework. If an educator does not have adequate safety training relative to the courses or activities they are teaching, school districts need to provide the appropriate training(s) as required by OSHA Standard 29 CFR 1910.30[92]. These safety training experiences are critical for ensuring safer teaching and learning as described in previous sections of this book and also presented in other publications resulting from this study[42,101].

GRADE LEVEL

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
K-5	2 (3)	6 (5)	3 (1)	6 (9)	0 (0)	4 (6)	21 (3)
6-8	23 (31)	35 (30)	89 (37)	17 (26)	25 (17)	18 (25)	207 (29)
9-12	35 (47)	62 (53)	137 (57)	35 (54)	84 (56)	41 (58)	394 (55)
6-12	12 (16)	8 (7)	10 (4)	5 (8)	40 (27)	7 (10)	82 (11)
K-12	2 (3)	6 (5)	1 (0.4)	2 (3)	2 (1)	1 (1)	14 (2)

Summary: The majority of the teachers in this study were middle school (29%) and high school (55%) teachers with a limited number of elementary STEM educators (3%). The middle Atlantic and south central regions had a higher percentage of elementary and K-12 educators in comparison to other regions. Educators from different grade levels may require unique safety training to address the needs of their students. Potential hazards and resulting risks associated with student activities require safety actions for safer teaching and learning experiences at all levels. There are a number of resources tailored toward addressing common STEM safety issues and pedagogy relative to elementary education[54,62,73,102] and secondary education[53,54,62,103].

DEGREE AREA(S)

Region	Degree	IA n (%)	TE n (%)	STEM Ed n (%)	Edu n (%)	Eng n (%)	Ind n (%)	Other n (%)
New England	AAS	2 (3)	2 (3)	0 (0)	3 (4)	7 (10)	3 (4)	1 (1)
	B.S.	0 (0)	15 (20)	3 (4)	1 (1)	11 (15)	0 (0)	12 (16)
	GC	1 (1)	4 (5)	1 (1)	2 (3)	1 (1)	1 (1)	0 (0)
	M.S.	8 (11)	20 (27)	10 (14)	14 (19)	1 (1)	2 (3)	9 (12)
	Doc	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)
Mid-Atlantic	AAS	0 (0)	1 (1)	0 (0)	2 (2)	5 (4)	11 (9)	2 (2)
	B.S.	0 (0)	49 (42)	3 (3)	5 (4)	7 (6)	2 (2)	8 (7)
	GC	1 (1)	6 (5)	7 (6)	9 (8)	1 (1)	1 (1)	0 (0)
	M.S.	8 (7)	18 (15)	4 (3)	41 (35)	2 (2)	3 (3)	7 (6)
	Doc	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
South Atlantic	AAS	4 (2)	2 (1)	0 (0)	10 (4)	13 (5)	8 (3)	18 (8)
	B.S.	0 (0)	57 (24)	2 (1)	32 (13)	24 (10)	6 (3)	50 (21)
	GC	2 (1)	9 (4)	9 (4)	11 (5)	0 (0)	3 (1)	5 (2)
	M.S.	8 (3)	46 (19)	11 (5)	64 (27)	8 (3)	4 (2)	19 (8)
	Doc	0 (0)	1 (0.4)	2 (1)	4 (2)	2 (1)	0 (0)	1 (0.4)
South Central	AAS	3 (5)	1 (2)	1 (2)	2 (3)	1 (2)	2 (3)	5 (8)
	B.S.	0 (0)	6 (9)	7 (11)	6 (9)	4 (6)	2 (3)	19 (29)
	GC	1 (2)	2 (3)	1 (2)	3 (5)	0 (0)	0 (0)	1 (2)
	M.S.	5 (8)	2 (3)	7 (11)	21 (32)	1 (2)	0 (0)	11 (17)
	Doc	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Note. IA = Industrial arts; TE = Technology/T&E education; STEM Ed = STEM education; Edu = Other education field; Eng = Engineering non-education; Ind = Industry; Other = Other area; AAS = Associates degree; B.S. = Bachelor's degree; GC = Graduate certificate; M.S. = Master's degree; Doc = Doctoral degree.

DEGREE AREA(S), CONTINUED

		IA n (%)	TE n (%)	STEM Ed n (%)	Edu n (%)	Eng n (%)	Ind n (%)	Other n (%)
Midwest	AAS	1 (1)	1 (1)	0 (0)	5 (3)	1 (1)	10 (7)	7 (5)
	B.S.	1 (1)	53 (35)	2 (1)	11 (7)	2 (1)	5 (3)	3 (2)
	GC	3 (2)	7 (5)	4 (3)	2 (1)	0 (0)	0 (0)	0 (0)
	M.S.	10 (7)	24 (16)	3 (2)	51 (34)	3 (2)	2 (1)	9 (6)
	Doc	0 (0)	1 (0.7)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)
West	AAS	4 (6)	3 (4)	1 (1)	1 (1)	5 (7)	7 (10)	4 (6)
	B.S.	0 (0)	20 (28)	3 (4)	5 (7)	4 (6)	2 (3)	11 (16)
	GC	4 (6)	1 (1)	0 (0)	4 (6)	1 (1)	2 (3)	0 (0)
	M.S.	1 (1)	10 (14)	2 (3)	15 (21)	2 (3)	1 (1)	3 (4)
	Doc	0 (0)	1 (1)	1 (1)	3 (4)	0 (0)	0 (0)	0 (0)
National	AAS	14 (2)	10 (1)	2 (0.3)	23 (3)	32 (5)	41 (6)	37 (5)
	B.S.	1 (0.1)	200 (28)	20 (3)	60 (8)	52 (7)	17 (2)	103 (14)
	GC	12 (2)	29 (4)	22 (3)	31 (4)	3 (0.4)	7 (1)	6 (0.8)
	M.S.	40 (6)	120 (17)	37 (5)	206 (29)	17 (2)	12 (2)	58 (8)
	Doc	0 (0)	3 (0.4)	3 (0.4)	8 (1)	3 (0.4)	0 (0)	1 (0.1)

Note. IA = Industrial arts; TE = Technology/T&E education; STEM Ed = STEM education; Edu = Other education field; Eng = Engineering non-education; Ind = Industry; Other = Other area; AAS = Associates degree; B.S. = Bachelor's degree; GC = Graduate certificate; M.S. = Master's degree; Doc = Doctoral degree.

Summary: The most common degree earned by participants was a bachelor's degree in technology education or T&E education. A high percentage of respondents had master's degrees in technology education or T&E education, but master's degrees in educational areas not related to T&E education or STEM fields were the most common graduate degree. In comparison to other regions, the South Atlantic and mid-Atlantic regions had a lower percentage of participants with Industrial Arts degrees. The south central region had a higher percentage of teachers with degrees in STEM or integrated STEM education, and the south Atlantic had a higher percentage of teachers with engineering degrees. Moreover, the mid-Atlantic and west regions had a higher percentage of teachers with industry related degrees. The south Atlantic and south central regions also had a higher percentage of educators from "other" areas not related to STEM education, education, or industry fields.

The results from this table provide insight about the types of formal training and coursework that teachers from each region have completed. It also sheds light on regions that may be hiring more traditionally prepared educators compared to those hiring educators from other career fields or content areas. This type of information can help school districts plan to provide additional safety training, especially for out of content educators who may have limited safety training or experience with education specific safety topics (classroom management, safety pedagogy, etc.).

CERTIFICATION(S)

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
T&E	61 (82)	102 (87)	199 (83)	20 (31)	130 (86)	45 (63)	557 (78)
Alternative Certification	3 (4)	1 (1)	5 (2)	6 (9)	5 (3)	2 (3)	22 (3)
CTE	3 (4)	1 (1)	19 (8)	9 (14)	10 (7)	16 (23)	58 (8)
Science	3 (4)	7 (6)	4 (2)	16 (25)	2 (1)	0 (0)	32 (5)
Elementary (K-6)	2 (3)	4 (3)	5 (2)	5 (8)	1 (1)	4 (6)	21 (3)
Other	2 (3)	2 (2)	7 (3)	9 (14)	3 (2)	4 (6)	27 (4)

Note. Teachers who were certified in T&E plus other content areas were classified only under the T&E certification category. Teachers without T&E certification were classified under what they indicated was their primary certification area.

Summary: Approximately 78% of teachers were certified in technology education/T&E education with the next largest categories being a CTE area or a science education area. The category labeled as other included educators teaching STEM classes who indicated they had certification in art, business, English, instructional technology, math, music education, or special education. These findings are consistent with previous studies[97,104] which found on average between 84-86% of T&E teachers in the U.S. have a standard T&E teaching certification. A high percentage of teachers in the New England (82%), middle Atlantic (87%), and Midwest (86%) regions were certified in T&E. The south central region had a high percentage of teachers certified in science and CTE areas. Additionally, the west had a larger percentage of CTE teachers than any other region. The classification of T&E as a CTE program of study in many western states may explain the high percentage of CTE certified educators teaching T&E related courses in this region. As Love and Roy[16] caution, certification does not always guarantee an educator has the required safety training relative to all materials, equipment, and processes conducted in a classroom, lab, or makerspace. In some states certification merely means a teacher passed the appropriate Praxis II exam. Therefore, even when a teacher has the appropriate certification, school districts must ensure they also have adequate safety training to prepare them for the potential hazards and resulting risks they may encounter within their courses and STEM or CTE facility.

MAIN TEACHING FOCUS

	New England n (%)	Mid-Atlantic n (%)	South Atlantic n (%)	South Central n (%)	Midwest n (%)	West n (%)	National n (%)
T&E literacy, T&E design	30 (41)	44 (38)	122 (51)	17 (26)	28 (19)	23 (32)	264 (37)
Pre-engineer-ing	10 (14)	10 (9)	44 (18)	26 (40)	24 (16)	3 (4)	117 (16)
Materials Processing: Woods	10 (14)	23 (20)	17 (7)	1 (2)	41 (27)	8 (11)	100 (14)
Electronics and Robotics	6 (8)	12 (10)	20 (8)	5 (8)	3 (2)	11 (16)	57 (8)
CAD	4 (5)	11 (9)	16 (7)	3 (5)	5 (3)	3 (4)	42 (6)
Materials Processing: Metals	4 (5)	4 (3)	2 (1)	0 (0)	22 (15)	0 (0)	32 (5)
Communica-tions	2 (3)	5 (4)	3 (1)	1 (2)	6 (4)	5 (7)	22 (3)
Construction	1 (1)	1 (1)	6 (3)	0 (0)	10 (7)	2 (3)	20(3)
Power & En-ergy	1 (1)	3 (3)	1 (0.5)	1 (2)	11 (7)	2 (3)	19 (3)
Elementary STEM	2 (3)	3 (3)	2 (1)	2 (3)	0 (0)	3 (4)	12 (2)
CTE	2 (3)	0 (0)	2 (1)	1 (2)	1 (1)	7 (10)	13 (2)

Summary: The majority of participants taught T&E literacy/design courses (37%) with pre-engineering (16%) and woods materials processing/manufacturing courses (14%) as the next closest categories. Regionally, the south Atlantic had the highest percentage of educators teaching T&E literacy/design courses (51%), the south central had the largest percentage teaching pre-engineering courses, and the Midwest had the largest percentage teaching materials processing courses in woods (27%) and metals (15%). These array of courses demonstrate the broad nature of T&E education programs across the country. Each of these courses may have common general safety criteria; however, they may also have very unique safety protocols and practices that require specific safety training. School districts must be cognizant about the courses they are offering, and the background and training of the instructors facilitating those courses. For example, if the instructor does not have documented coursework or indus-

try experience with safety training directly related to the equipment and processes they will be expected to use in their teaching (e.g., MIG welding in a metals materials processing course), then the employer has a responsibility to ensure the instructor receives the appropriate training to maintain a safer teaching and learning environment for all.

Safety Note: Photo shows several young students working with liquids and having only eye protection (i.e., safety goggles) for personal protective equipment (PPE). Potential hazardous liquids warrant additional PPE for hands (e.g., nitrile gloves) and body (e.g., non-latex apron or lab coat). Also liquid containers need to be labeled.

APPENDIX B

RESULTING RESEARCH

The following research is a result of this data set:

Publications

Love, T. S. & Roy, K. R. (2021). Key findings from Wisconsin's responses to the 2020 national T&E education safety survey. *Interface: Journal of the Wisconsin Technology Education Association, 61*(1), 22-23.

Love, T. S., Roy, K. R., & Sirinides, P. (2021). What factors have the greatest impact on safety in Pennsylvania's T&E courses? *Technology and Engineering Education Association of Pennsylvania Journal, 69*(1), 5-22.

Additional publications resulting from this study will be added to the following website as they are published. Please visit the website to view the most current list of publications: https://www.iteea.org/SafetyReport.aspx

Blogs

Roy, K. (2021, June 1). Safer engineering instruction in K-12 labs and makerspaces: Results from a 2020 national study. *National Science Teaching Association (NSTA) Safety Blog.* https://www.nsta.org/blog/safer-engineering-instruction-k-12-labs-and-makerspaces-results-2020-national-study

Conference Papers

Love, T. S., Sirinides, P., & Roy, K. R. (2022). Examining factors associated with accidents in CTE and STEM education labs: A national safety study. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Conference Presentations

Love, T. S. & Roy, K. R. (2021, March). *The 2020 national T&E safety study results*. Presentation at the annual meeting of the International Technology and Engineering Educators Association, Virtual Conference.

Love, T. S. & Gill, M. (2020, October). *Maryland's results from the 2020 T&E education safety survey*. Presentation at the annual meeting of the Technology and Engineering Educators Association of Maryland, Virtual Conference.

Webinars

Love, T. S. & Roy, K. R. (2021, April). *Pennsylvania's results from the 2020 T&E education safety survey: Comparing to the national averages and recommendations to address areas of concern.* Invited webinar for the Technology and Engineering Education Association of Pennsylvania. Harrisburg, PA.

Love, T. S. (2020, October). *New Jersey's results from the 2020 national T&E education safety survey.* Invited webinar for the New Jersey Technology and Engineering Educators Association. Monmouth Junction, NJ.

Safety Recommendations Supported by Research

For decades safety has been an integral component of STEM (science, technology, engineering, and mathematics) and CTE (career and technical education) instruction. Given today's litigious society, safety in STEM education and CTE has received greater attention. This in part is the result of the rise in popularity of collaborative learning environments like makerspaces and fabrication labs. While safety has been recognized as critical to hands-on interdisciplinary teaching and learning experiences relative to STEM and CTE, there is limited research data to support appropriate recommendations for safety policies and practices.

This book utilizes findings from one of the most extensive national STEM and CTE safety research studies to date (718 teachers across 42 states) to provide practitioner friendly safety recommendations with suggested resources. The recommendations provide implications for state education departments, professional associations, school districts/boards of education, administrators, and teachers to make data informed decisions regarding safety policies and practices to enhance STEM and CTE instruction.

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