FACTORS WITH THE GREATEST IMPACT ON SAFETY IN PENNSYLVANIA'S T&E COURSES

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INTRODUCTION

Safety has been and continues to be one of the foundational pillars of technology and engineering (T&E) education. Evidence of its importance can be found in Pennsylvania's legislative codes (Love, 2013; PDE, 2002) and General Safety Law (No.174, P.L.654) with which public school districts must comply. The General Safety Law has state specific criterion that are similar to federal OSHA regulations, however it is important to note that this law does not apply to private schools which are required to adhere directly to the federal OSHA guidelines (Pennsylvania Department of Labor and Industry, 2021).

In addition to the aforementioned legal statutes, safety is core component of better professional practices called for within curricula and standards documents. For example, safety concepts were conscientiously embedded throughout the Standards for Technological and Engineering Literacy (STEL) (ITEEA, 2020) as well as the proposed Pennsylvania Standards for Technology and Engineering Education (Grades 6-12) (PDE, 2020). A recent analysis by a panel of K-12 STEM education safety specialists from across the U.S. found that the STEL had a greater emphasis on safety than other current STEM-related standards and framework documents (Love et al., 2020). The proposed Pennsylvania standards (which are based heavily on the STEL) were also mentioned in that study as an exemplar for states to purposefully embed safety within their standards. More importantly, T&E educators have a legal and professional obligation to comply with all safety statutes and demonstrate appropriate professional safety practices that are the established precedent from recent court rulings, as well as publications from PDE and organizations such as TEEAP and ITEEA (Love, 2013, 2014). This article presents data supported recommendations which school districts would be wise to follow because this document could be admissible in future accident cases to help establish a new precedent for safer T&E instruction.

PREVIOUS RESEARCH

From years of T&E education safety work across the country, the authors have identified some commonly shared concerns. Specifically, teachers often cite class occupancy (number of people in a class/lab), percentage of students with disabilities in a class, classroom management, facility size and safety controls, funding for safety items/improvements, school administration support, and safety training as areas of substantial concern. Unfortunately, there are a limited number of empirical studies that have examined these safety issues in K-12 labs, and in many cases, there is no prior research examining these issues specifically within a T&E education context. This is surprising given the important role safety has played from manual arts to present day T&E education courses. A lack of data supported findings can yield skepticism among state departments and school districts who have discretion over adopting safety recommendations beyond those mandated by state statutes.

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There are a few studies which demonstrate the positive impact that high quality T&E safety training can have on educators. One study found that when professional development (PD) about engineering design was delivered by T&E educators, teachers reported statistically greater awareness and self-efficacy toward safely using tools and materials than their colleagues who completed a similar PD led by science educators (Love, 2017). In another study it was found that PD delivered by a T&E educator resulted in significant gains in teachers' self-efficacy and expected outcomes related to the safer use of tools and materials in makerspaces (Love, 2018).

In regard to research examining factors that have the greatest impact on K-12 lab/shop safety, the closest related studies come from Career and Technical Education (CTE). Threeton and Evanoski (2014) surveyed 60 CTE teachers in central Pennsylvania and found that chronic student absences, accommodating students with special needs, and lack of funding were the greatest perceived obstacles for safer CTE programs. Moreover, there are a number of resources that address the most commonly voiced issues of occupancy load and facility size relative to T&E labs, however the class occupancy requirements cited within publications by PDE and ITEEA come from science education studies (PDE, 2002; West, 2016). Class occupancy load limits are derived from the National Fire Protection Association (NFPA) 101 Life Safety Code based on net square footage for facilities hosting lab activities as explained by West (2016). One of the most notable lab safety studies found that the rate of accidents significantly increased when either, a) the number of students in a lab exceeded 24 per one instructor, or b) the amount of work space per student decreased from the 50 square feet mandated by the NFPA 101 Life Safety Code (Stephenson et al., 2003). While these studies from CTE and science education have applications to T&E labs, there is currently no data like this specific to T&E education settings. This article addresses that critical gap by providing such data.

Due to the extensive nature of the survey, only key findings relative to the focus of this article are presented.

The full results from Pennsylvania teachers can be accessed at https://sites.google.com/view/2020-te-safety-study/

RESEARCH AND ANALYSES METHODS

This study used the 2020 T&E Education - Facilities and Safety Survey (TEE-FASS) to collect responses via online survey software in the spring of 2020. The TEE-FASS was developed by making minor modifications to the 2001 Texas Science Safety Survey (Stephenson et al., 2003) to more accurately represent safety issues unique to T&E education. The instrument was reviewed by two national STEM education safety specialists and pilot tested among a small sample of T&E teachers to make additional changes and establish face validity. It was then advertised by ITEEA and TEEAP which yielded 718 total responses from 42 states, of which 67 responses (9% of the national sample) were teachers from Pennsylvania school districts. For the purpose of this article, only responses from Pennsylvania teachers were examined for the descriptive statistics, and the full national sample was analyzed for the correlation and logistic regression tests. These tests were conducted by one of the authors who holds a Ph.D. in quantitative methods from the University of Pennsylvania.

RESULTS

Demographics

Before presenting the statistical analyses, some key demographic and background information about participants must be disclosed. Among Pennsylvania respondents, 84% identified as male, 97% were White, 37% and 47% earned bachelor's degrees in Industrial Arts (IA) or Technology/T&E education respectively, 62% had been teaching IA or T&E for 16+ years, and most teachers taught grades 6-8 (31%), grades 9-12 (52%), or grades 6-12 (4%).

Safety Training

The majority of teachers reported receiving safety training in their undergraduate technical lab courses (81%) or undergraduate T&E teaching methods courses (75%). Approximately 16% indicated they did not receive safety training in their T&E teaching methods courses, and 9% said they never completed a methods course. Additionally, only 9% reported receiving some form of safety training when initially hired by their district, and 84% had not received any form of safety training or update in over a year.

Teaching Conditions

When asked what the average number of different courses was they had to prep for each semester of the 2019-2020 academic year, 34% reported three classes, 25% reported four classes, and 25% reported five or more classes. Pertaining to the foci of courses taught throughout the year, 63% reported teaching at least one class about T&E Design/T&E literacy, 49% said Materials Processing: Woods, 43% said CAD or 3D Modeling, and 37% said Electronics/Programming/Robotics.

Facilities Characteristics

Regarding the type of facility where T&E activities were conducted during the academic year, 63% indicated in a T&E classroom/lab combination facility, 18% reported in a dedicated T&E lab, 13% said in a regular classroom or computer lab, and 4% indicated they worked in a makerspace. There were various other factors asked about facilities. A brief summary of some key findings is presented below:

- 37% had safety zones taped on the floor around hazardous equipment,
- 62% had either a plumbed or portable eyewash station within 10 second access of hazardous areas,
- 55% had a fully stocked first aid kit in their lab (only 18% of those said the school or district restocked them each semester),
- 35% had adequate recycled air ventilation in their lab or classroom,
- 87% had lockable storage cabinets,
- 54% believed they had sufficient storage space,
- 71% had a finishing room or chemical storage area (83% said it could be locked),
- 79% had an accessible emergency master power shut-off for electric, gas, or water,
- 52% had students conduct soldering activities, of which 23% had a soldering fume hood or portable fume extractor,
- 25% had their students conduct welding, casting, or molding activities. Among these teachers 88% of indicated they had enough personal protective equipment (PPE) for each student conducting such activities,
- 79% had a 3D printer in their lab, of which 77% of these teachers indicated they had no fume hood or air filtration system to accompany their printer.

Instructional and Administrative Practices

Only 25% of teachers reported that their school nurse had a copy of Safety Data Sheets (SDS) for hazardous items used in their classes, while 66% reported their department maintained copies and only 45% reported their district safety officer retained copies. Approximately 64% of teachers said they required students and parents/guardians to sign a safety acknowledgment form for their class, and only 79% indicated students were required to pass a safety test prior to using hazardous tools/equipment/materials. When asked about their source for safety tests, 60% said they used teacher developed resources, 12% used school district or department developed tests, 12% used the safety resources developed by PDE, and 7% used the resources from ITEEA's safety website.

Regarding PPE, only 88% said they had ANSI/ISEA Z87.1 D3 rated safety glasses with side shields for each student working with solid materials in their T&E lab, and 54% had a UV light cabinet or approved procedure for sanitizing eye protection. When conducting lab activities, 87% indicated they always required students to wear impact rated safety glasses when working with solids in comparison to 24% who always required students to wear indirectly vented safety goggles when working with liquids. Additionally, 84% of teachers said they required students to secure long hair, 81% said they make students remove loose jewelry and secured baggy clothing/long sleeves, and only 61% required students to wear close-toed shoes. Only 9% of teachers reported testing their eyewash station for at least two minutes every week.

Only 9% reported receiving some form of safety training when initially hired by their district, and 84% had not received any form of safety training or update in over a year.

Administrative Support and District Policies

A key component of safer T&E programs is administrative and district support. When asked how they would rate their administration's progressive disciplinary support in regard to dealing with safety incidents, 42% said excellent, 42% said good, 15% said fair, and 1% said poor. In addition to disciplinary support, 36% indicated they did not feel they had a sufficient budget to purchase and maintain the necessary safety controls for their T&E courses. Moreover, 28% of teachers said their district had safety guidelines and a policy for PPE, 80% said they had a teacher developed policy, 81% and 55% said their T&E classes and department respectively had their own written safety policy, and 39% reported their district conducts annual safety audits.

Facility Size and Occupancy Load

The size of teachers' T&E instructional areas is summarized in *Table 1*.

In addition to the size of their instructional area, only 58% believed they had sufficient work space to account for the number of students in their classes.

Approximately 52% of teachers reported their average class size was 16-20 students while 19% reported an average of 21-24 students. When asked what their largest class size was during the 2019-2020 academic year, 33% indicated 21-24 students while 25% said 25-30 students. Additionally, 45% of participants said that 6-15% of their students had special needs, while 34% reported 16-25% of their students had special needs. However, 52% indicated they had a lab station or work area accessible to students with mobility disabilities.

Approximate Size of the Instructional Area Used to Conduct T&E Activities

Answer	n (%)
Less than 600 square feet	3 (4)
600-800 square feet	8 (12)
800-1,000 square feet	17 (25)
1,000-1,200 square feet	16 (24)
Greater than 1,200 square feet	23 (34)

Table 1. Approximate size of the instructional area used to conduct T&E activities.

Safety Incidents and Accidents

The survey asked teachers to report information regarding safety incidents (no injury), minor accidents (required minor medical attention), and major accidents (required major medical attention like stitches or a hospital visit) that occurred within the past calendar year in their classes. The majority of teachers (67%) reported 1-10 safety incidents occurred, with the top causes being hot glue guns (36%), student operated equipment (31%), and hand or portable power tools (18%). Sixty percent of the teachers reported 1-5 minor accidents, while 21% said they had 6-10 occurrences. Only 10% of teachers reported major accidents occurring, all of which happened between 1-5 times that year. Teachers were also asked to report on minor accidents that occurred over the past five years of their teaching. The majority fell in the middle categories reporting 1-10 (42%), 11-20 (22%), or 21-30 (18%) occurrences over a five-year span. Regarding major accidents over the past five years, 58% reported none while 42% had 1-10 major accidents. These injuries mostly involved students (75%) and resulted in cuts/lacerations (76%) or burns (45%). The most commonly injured body part was a hand or finger (87%). Hot glue guns (27%), hand tools (ranging from items such as utility knives to hammers) (24%), and band saws (12%) were the most common items involved in the accidents. Lastly, when asked what factor they believed was the greatest contributor to unsafe conditions/accidents in

the T&E lab, teachers selected student failure to follow safety protocols (29%), overcrowding (21%), inclusion of students with various disabilities (9%), and classroom management/ discipline (9%).

Statistical Analyses

In addition to looking descriptively at the frequencies and percentages discussed in previous sections, two types of statistical analyses were conducted to empirically investigate: 1) What teaching conditions and practices contribute to or protect against safety accidents, and 2) What types of training protect against safety accidents. For these analyses the national data set of 718 participants was examined to provide more statistically reliable results than the smaller sample of teachers from Pennsylvania.

Teaching Conditions and Practices Associated with Safety Accidents

To investigate this issue, polychoric correlation tests were conducted and a number of factors were found to have a statistically significant correlation with accident occurrence at the 0.05 level. Some notable factors contributed to an increase in accidents (contributing factors), while others were associated with a decrease in accidents (reducing factors). Those factors are listed in *Tables 2* and *3*.

Teaching Conditions and Practices Associated with Safety Accidents

A series of predictive models using logistic regression tests were conducted to examine what types of pre-service and in-service training served as predictors of accidents. The data revealed that training received from a higher education technical course or T&E teaching methods course alone, or from their district alone, did not significantly decrease the chance of an accident occurring. However, we found that teachers who received a combination of safety training in their higher education coursework, from

Statistically Significant Factors that Contributed to Accidents	
Contributing Factor	**Details**
Type of courses taught	Ex.) 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 that indicated they have a table saw, there were significantly more accidents reported among those that 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.

Table 2. Statistically significant factors that contributed to accidents.

Statistically Significant Factors that Reduced Accidents
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 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 on the floor near hazardous equipment/tools
Non-skid strips on the floor near hazardous equipment
Type of table saw: SawStop

Table 3. Statistically significant factors that reduced accidents.

their district when initially hired, and during in-service safety training updates from their district or an external source during their time of employment had a 37% lower chance of having an accident occur in their T&E courses. Overall, findings reveal there are multiple factors that impact the chance of an accident occurring. Additional analyses are needed to control for the variables collected through the survey and further examine their influence. The results from the statistical analyses merely provide a snapshot of some of the significant factors and predictors found. Greater details about these statistical analyses will be described in future research focused articles.

RECOMMENDATIONS FROM THIS STUDY

As with any study there are a number of limitations that must be considered. This study merely presents data voluntarily self-reported by 67 T&E teachers in Pennsylvania. The survey was administered in April 2020, shortly after COVID-19 caused many schools to transition to online learning, however teachers did have face-to-face classes for the majority of their academic year to reflect on for the survey. This study does not represent the safety practices of every school district or teacher; however, it provides a sample from various districts and teachers across the Commonwealth. In future studies the data could be further analyzed to differentiate findings according to various subgroups (ex. years of teaching experience, courses taught, grade level taught, etc.) and examined in more detail from a national level.

A few alarming statistics emerged from this study. Fifty percent of teachers reported having 4-5 preps per semester which could place increased safety responsibilities on teachers (e.g., additional set up and maintenance). Specifically related to facilities, there was a noticeable lack of safety zones, access to eyewash stations, fully stocked first aid kits, emergency power shut-off controls, ventilation for soldering, and PPE for welding in T&E labs. Teachers should ensure that their T&E lab has the appropriate engineering controls, standard operating procedures, PPE, and safety communications that are critical to reducing the severity of accidents. Air filtration is also something that districts should invest in for their 3D printers. Emerging studies have found hazardous levels of ultrafine particles are often emitted from desktop 3D printers.

School nurses, T&E departments, district safety officers, and the local fire marshal should all have a copy of SDS for hazardous materials/chemicals found in T&E labs within your school. Some areas of grave concern were the lack of a signed safety acknowledgment form, passing safety tests, use of safety glasses/goggles, securing long hair and loose jewelry/clothing, and wearing of closed toed shoes before any student was allowed to conduct work in the lab. These should all be requirements prior to any lab activity being conducted. Furthermore, state statutes require appropriate eye protection (Act 116) and PPE (Act 174) for all school lab/shop activities (PDE, 2002). Hardly any teachers reported testing their eyewash for several minutes every week as called for by the ANSI/ISEA Z358.1-2014 eyewash/shower standard. Districts should have written safety policies for lab activities and facilities that comply with Act 116 and Pennsylvania's General Safety Law. They should conduct annual safety audits of labs and inventories of hazardous chemical/materials. T&E departments should also work to develop a safety policy aligned with their district's policies to ensure fair and consistent safety practices are implemented across the department.

Moreover, there was an identifiable lack of safety training participants reported receiving from their undergraduate T&E teaching methods course. Teacher preparation programs and mentor teachers should ensure safety is a core focus for all pre-service teachers. There was also an identifiable lack of safety training provided by districts. OSHA requires employers (school districts) to train employees (teachers) upon initial hiring and anytime thereafter a new hazard (e.g., new equipment, new chemical, etc.) is to be used in the workplace. This lack of safety training along with some of the other items mentioned in this section were found to significantly contribute to accidents in the statistical analyses.

Air filtration is also something that districts should invest in for their 3D printers. Emerging studies have found hazardous levels of ultrafine particles are often emitted from desktop 3D printers.

The strongest findings presented in this study are the statistical analyses which revealed that comprehensive safety training has a significant and beneficial effect on reducing accidents. Additionally, a number of factors were found to contribute to or reduce accidents (*Tables 2* and *3*). Teachers, school district administrators, and school district health and safety officers should review these factors and address any related issues pertaining to their facilities and practices. The data suggests that doing this will help reduce the chance of an accident occurring. Additionally, the Pennsylvania Department of Education and school districts should review these findings to inform future safety recommendations and policies.

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CONCLUSION

The findings from this study provide a clearer picture about the current status of safety in T&E education programs across a sample of Pennsylvania school districts. This study reaffirms findings published by previous studies that indicated comprehensive safety training plays a critical role in providing safer T&E instruction. In addition, this study provides sound empirical evidence specific to T&E safety topics which could serve as a more relevant precedent than previous studies from other content areas. While science educators continue to integrate more engineering practices as called for by the Next Generation Science Standards, this study sheds light on the hazards associated with facilitating engineering design activities and the importance of appropriate safety training and protocols. It is strongly recommended that teachers present this research to their administration and request support in writing to address the factors found to influence the chance of an accident occurring. In the event that an accident does occur, solicitors (attorneys) or expert witnesses may present this research and other resources with similar recommendations as a precedent which districts had knowledge of and neglected to follow. It would be better professional safety practice for school districts to follow the research supported recommendations presented in this article than to knowingly create unsafe conditions due to lack of training, lack of PPE, lack of engineering controls, overcrowding, and other critical safety issues discussed in this article. ■

REFERENCES

Commonwealth of Pennsylvania Department of Labor and Industry. (2021). *General safety.* https://www.dli.pa.gov/Individuals/Labor-Management-Relations/bois/Pages/General-Safety.aspx

International Technology and Engineering Educators Association (ITEEA). (2020). *Standards for technological and engineering literacy: The role of technology and engineering in STEM education.* https://www.iteea.org/stel

Love, T. S. (2013). Using case law to address technology and engineering education safety and liability in the Commonwealth of Pennsylvania. *Technology and Engineering Education Association of Pennsylvania Journal, 61*(2), 6-8.

Love, T. S. (2014). Safety and liability in STEM education laboratories: Using case law to inform policy and practice [Electronic supplement]. *Technology and Engineering Teacher, 73*(5), 1-13. http://www.iteea.org/File.aspx?id=86487&v=52ffd40f

Love, T. S. (2017). Perceptions of teaching safer engineering practices: Comparing the influence of professional development delivered by technology and engineering, and science educators. *Science Educator, 26*(1), 1-11.

Love, T. S. (2018). *Perceptions of safety in makerspaces: Examining the influence of professional development.* Paper presented at the 105th Mississippi Valley Technology Teacher Education Conference, Nashville, TN. http://www.mississippivalley.org/wp-content/uploads/2018/11/Perceptions-of-Safety-in-Makerspaces-Love.pdf

Love, T. S., Duffy, B. C., Loesing, M. L., Roy, K. R., & West, S. S. (2020). Safety in STEM education standards and frameworks: A comparative content analysis. *Technology Teacher, 80*(3), 34-38.

Pennsylvania Department of Education. (PDE). (2002). *Safety guidelines for elementary and technology education teachers.* https://www.education.pa.gov/Documents/Teachers-Administrators/Curriculum/Technology%20Education/Safety%20Guidelines%20Science.pdf

Pennsylvania Department of Education (PDE). (2020). *Pennsylvania technology and engineering standards (grades 6-12).* https://www.education.pa.gov/Teachers%20-%20Administrators/Curriculum/Science/Pages/Science-Standards.aspx

Pennsylvania Department of Labor and Industry. (2021). *General safety.* https://www.dli.pa.gov/Individuals/Labor-Management-Relations/bois/Pages/General-Safety.aspx

Stephenson, A. L., West, S. S., Westerlund, J. F., & Nelson, N. C. (2003). An analysis of incident/accident reports from the Texas secondary school science safety survey, 2001. *School Science and Mathematics, 103*(6), 293-303. https://doi.org/10.1111/j.1949-8594.2003.tb18152.x

Threeton, M. D., & Evanoski, D. C. (2014). Occupational safety and health practices: An alarming call to action. *Career and Technical Education Research, 39*(2), 119-136. https://doi.org/10.5328/cter39.2.119

West, S. S. (2016). Overcrowding in K-12 STEM classrooms and labs. *Technology and Engineering Teacher, 76*(4), 38-39.