Examining Factors Associated with Accidents in CTE and STEM Education Labs: A National Safety Study

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Abstract

Safety continues to be one of the core components of career and technical education (CTE) and science, technology, engineering, and mathematics (STEM) education. Evidence of its importance can be found in many state statutes, approved state OSHA plans, federal OSHA regulations, national and state academic standards documents, and resources published by professional CTE and STEM educator associations such as ACTE, NSTA, and ITEEA. This paper presents safety findings from a study involving 718 educators from 42 states who taught lab based CTE or STEM courses. Correlational analyses revealed factors which were associated with accident occurrences. This study provides practical implications for state departments and school districts to improve the safety practices, protocols, and policies within CTE and STEM education labs.

Purpose

The overarching purpose of this research was to provide sound empirical evidence that identified safety factors, practices, and facility characteristics associated with accident occurrences in career and technical education (CTE) and science, technology, engineering, and mathematics (STEM) education labs. The lack of data from previous studies and implications for

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protecting students and teachers provided the rationale for this study, which resulted in the following research questions: 1) What factors are significantly associated with accident occurrences, and 2) What is the extent of these associations?

Theoretical Framework

Safety concepts and practices, including but not exclusive to tool, equipment, and chemical safety, have long been a core component of CTE and STEM related instruction dating back to early manual arts programs (Love, 2019). Safety continues to serve as one of the core tenets embedded throughout today's K-12 CTE, science education, and technology and engineering (T&E) education programs and standards. As Love et al. (2020) pointed out, the importance of safer facilities and instructional practices are emphasized in key CTE and STEM education documents like the *2018 ACTE Quality CTE Program of Study Framework* (Imperatore & Hyslop, 2018), the *Standards for Technological and Engineering Literacy (STEL)* (ITEEA, 2020) and the *Standards for Science Teacher Preparation* (Morrell et al., 2020). Moreover, CTE and STEM educators have a legal and professional obligation to ensure appropriate professional safety practices are always upheld, such as those published by applicable state and national organizations (e.g., ACTE, ITEEA, NSTA, federal OSHA, and state OSHA plans). (Love, 2013, 2014; Roy & Love, 2017).

There are a number of studies which have investigated safety topics relative to CTE and STEM education. Although many of these examined discipline specific topics, Love (2015) demonstrated how the overlap among CTE and STEM education safety resources could benefit initiatives in both fields. For example, both CTE administrators and T&E educators in Idaho indicated that teaching proper safety attitudes and proper safety practices in the lab were two of the most important competencies needed to manage a CTE or T&E course (Cannon, et al. 2011;

Cannon et al. 2013). Occupancy load is another area of overlap which has been beneficial for promoting safer learning conditions in CTE, science education, and T&E education. The square footage requirements set by the National Fire Protection Association (NFPA) 101 Life Safety Code apply to every school lab or shop whose states have adopted the NFPA codes/standards. Additionally, research on the correlation between occupancy load and accident rates in labs (Stephenson et al., 2003) has been used as the foundation for lab occupancy recommendations published by professional CTE and STEM education associations (NSTA, 2020; West, 2016).

Further overlap can be observed from Threeton and Evanoski's (2014) research in which CTE teachers identified chronic student absences, accommodating students with special needs, and lack of funding as the greatest perceived obstacles for safer CTE programs. In a later study (Love & Roy, 2022) T&E educators voiced similar concerns, identifying student failure to follow safety protocols, overcrowding, accommodating students with special needs, and classroom management/discipline as the greatest causes for unsafe conditions in labs. This study also revealed a significant correlation between instructors' level of safety training and accident occurrences. Safety training has been found to significantly increase teachers' perceptions regarding the use of tools and materials in STEM activities (Love, 2017a, 2017b; Love, 2022; Love et al., 2022). However, there is very little research analyzing injuries and causes of accidents in CTE (Utah Department of Health, 2007) and STEM labs (Love & Roy, 2022; Love et al, 2021; Stephenson et al., 2003; West & Kennedy, 2014). This study addresses that critical gap, examining what factors are significantly associated with accident occurrences.

Methods

Instrumentation and Data Sources

The 2020 T&E Education - Facilities and Safety Survey (TEE-FASS) (Love & Roy, 2022; Love et al., 2021) was administered online in the spring of 2020. The TEE-FASS was slightly modified from Stephenson et al.'s (2003) instrument to represent safety issues specific to current day CTE and STEM education labs. This instrument asked a series of questions related to demographics, experience, facilities, safety training, and accidents. To establish face validity, the instrument was reviewed by two national STEM education safety specialists and pilot tested among a small sample of CTE and STEM teachers to make additional changes. It was then advertised by state and national CTE and STEM education professional associations which yielded responses from 718 teachers across 42 states.

Participants

Among the 718 respondents 74% identified as male, 90% were White, and 5% were Black. Approximately 59% indicated they were currently teaching in a CTE related area according to their state classification of CTE (which encompassed T&E and pre-engineering courses in many states), and 80% were classified as teaching courses with increased hazards (construction, manufacturing processes, biotechnology, etc.). Regarding certification, 49% were certified to teach T&E education, 18% in a CTE area, 8% in a science area. Teachers had an array of degrees earned, including 6% with an associate's degree in an industry area and 5% with an associate's degree in an engineering field. In terms of bachelor's degrees, 30% were in T&E education, 7% were in engineering fields, and 2% were in industry areas. Furthermore, 28% and 23% had been teaching CTE or T&E courses for 16-25 years and >26 years respectively. Most teachers taught grades 6-8 (29%), 9-12 (55%), or 6-12 (11%).

Data Analyses

Exploratory correlational analyses were conducted to estimate the independent statistical associations of various factors (teaching conditions, facility characteristics, education and training experiences, etc.) with the occurrence of minor and major accidents over a 5-year period. Measures of association between accident occurrences and teaching conditions/practices were estimated as polychoric correlations using the full analytic sample. This approach is appropriate for survey items with limited response options. For these analyses we made no hypothesis about the direction of correlations and tested each at the .05 level of significance. We report the results for risk factors (positive correlation) and protective factors (negative correlation), organized by the strength of association. Those with correlation values greater than .30 were identified as major, those greater than 0.20 as moderate, and anything statistically significant but less than 0.20 was labeled as minor.

Results

The analyses revealed five risk factors and seventeen protective factors associated with minor and major five-year accident occurrences. Table 1 presents the teaching conditions/practices and facilities characteristics associated with five-year accident occurrences in either the positive (risk factor) or negative (protective factor) direction. All correlations presented in Table 1 were found to be statistically significant, with type I error rate of less than 0.05.

Simply stated, teachers of courses with increased hazards (construction, manufacturing processes, biotechnology, etc.), classes in which students were engaged in hands-on lab activities greater than 25% of the time, and rooms including a lab area were all significantly associated with higher minor and major accident occurrences. In addition, classes in which students were allowed to independently operate a table saw, and classrooms which had carpet in the lab area were minor yet significant risk factors (Table 1).

The polychoric correlations analysis revealed many factors that were significantly associated with reduced minor and major accident occurrences. Three major protective factors included having a dust collection system that was connected directly to equipment, circuit breakers which were tripped within the last year, and an adequate number of safety glasses with side shields for every student in a class. A number of other factors were found to have either moderate or minor associations with reduced five-year accident occurrences. To assist with the interpretation of the results, Table 2 displays the prevalence of the risk factors according to accidents reported. This table demonstrates a rise in the prevalence of accidents for each risk factor among all teachers that reported at least one major accident (n=225), at least one minor accident (n=384), or no accidents (n=109). Additionally, Table 3 demonstrates the prevalence of protective factors according to accidents reported. This table demonstrates an increase in no accident occurrences for each protective factor among all teachers that reported no major accident occurrences (n=493), no minor accident occurrences (n=110), or no accidents of any kind (n=109).

Scientific and Scholarly Significance

There are a few limitations with this study. The data was voluntarily self-reported shortly after COVID-19 transitioned most learning to online, but participants did have face-to-face classes for the majority of the 2019-2020 academic year to report on. Although the results cannot be generalized to every school district or state, this study does provide a much broader sample in comparison to previous studies. Despite these limitations the significance of this unique study is discussed below.

Risk Factors

When examining factors associated with increased accident occurrences there are some which are very clear and others which involve more explanation. It is reasonable to assume that more hazardous course content and more time spent doing hands-on lab activities would pose greater opportunities for accidents. Although important aspects of CTE and STEM education, this study supports claims that hazardous content and lab time pose major risk factors. This study is not suggesting to remove those aspects, but rather ensure proper engineering controls, safety practices, and personal protective equipment (PPE) are all being used to reduce the chance and severity of an accident. The moderate risk factor of activities being conducted in a facility with a lab (including hybrid classroom/lab designs) highlights the importance of required engineering controls and layout, especially with the rise of makerspaces in schools and libraries (Love, 2022; Love & Roy, 2018). Independent student use of a table saw was significantly associated with major accident occurrences unlike directly supervised and instructor assisted table saw use. Carpet in the lab area was a minor risk factor. This could have been due to increased flammability, and difficulty to clean and sanitize.

Protective factors

A number of factors were significantly associated with reduced accident occurrences. Safety glasses with side shields for every student were a major protective factor. Additional PPE items were moderate and minor protective factors, such as non-latex gloves, ear protection, and non-latex aprons. In terms of engineering controls, dust collection systems, circuit breakers that tripped, fire extinguishers within 25 feet of areas where hazardous activities were being performed, master shut off valves/switches, and ground fault circuit interrupter (GFCI) outlets were all found to be protective factors. Dust collection connected directly to the source without impeding the safe function of the equipment helps to cut down on wood dust and other particles that can create slip and breathing hazards. Circuit breakers being tripped signified proper function and prevented additional harm. Related to engineering controls was the flushing of eye wash stations which was found to be a minor factor. Lastly, a number of facilities characteristics and safety practices were protective factors. These included having a separate finishing chemical storage room, lockable flammables cabinets, lockable storage cabinets, a sink in the facility, safety zones on the floor, and non-skid strips near equipment. Lockable chemical storage and tool storage cabinets help to limit theft and unapproved use of hazardous materials, reducing liability and accidents (Love & Roy, 2017, 2018; Roy & Love, 2017). Safety zones, and non-skid strips and/or rubber matting near equipment are both very inexpensive yet important safety practices to reduce liability and accidents (Love & Roy, 2017, 2018; Roy & Love, 2017). Furthermore, among teachers who reported using table saws in their labs, those who had a table saw with the patented SawStop safety technology reported significantly less major accident occurrences than teachers who had a table saw without the SawStop safety feature. Given the high risk of an accident associated with operating a table saw and the horrific nature of table saw accidents documented in the case law (Love, 2013), the findings in this study indicate that school districts would be wise to invest in a SawStop table saw to significantly reduce the chance and severity of an accident (Love & Roy, 2022).

Significance for Future Research and Practice

The analytical approach and findings presented in this paper are unique from past studies, specifically the correlation of various factors with accident occurrences in K-12 CTE and STEM labs. Findings from this study can be helpful for state departments, professional education associations, school systems, and teachers to reevaluate their safety policies and practices, and support requests for additional safety resources shown to reduce the chance or severity of an accident. While many schools are facing budget difficulties this study clearly demonstrates why critical safety resources are necessary for CTE and STEM labs. The findings from this study also generate additional questions regarding safety in CTE and STEM education. Future studies should investigate the effect of additional variables (e.g., years of teaching experience) on the significant factors identified in this study. Associations between specific courses and predicted safety factors, facilities characteristics, and other criteria should also be investigated (e.g., the association between dust collection systems and accident occurrences in construction and manufacturing courses).

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Table 1

Safety factors associated with accident occurrences over a five-year span

	Minor Accidents ρ		Major Accidents ρ	
Risk Factors				
Major				
Course with increased hazards	0.33	***	0.26	**
>25% class time doing hands-on activities	0.22	***	0.22	***
Moderate				
Facility with a lab area	0.27	***	0.13	**
Minor				
Independent student use of table saw	0.08		0.22	**
Carpet in lab area	0.12	~	0.18	*
Protective Factors				
Major				
Dust collection system connected directly to equipment	-0.35	***	-0.38	***
Circuit breakers tripped in last 12 months	-0.30	***	-0.36	***
Safety glasses w/ side shields for every student	-0.34	***	-0.31	***
Moderate				
Separate finishing/chemical storage room	-0.25	***	-0.28	***
Fire extinguisher within 25 feet	-0.27	***	-0.26	**
Ear protection available for every student	-0.22	***	-0.21	**
Non-latex gloves available for every student	-0.22	***	-0.21	**
Master shut offs for electricity, gas, and water	-0.22	***	-0.20	**
GFCI Outlets	-0.22	***	-0.14	*
Lockable flammables cabinets	-0.26	***	-0.16	*
Lockable tool storage cabinets	-0.20	**	-0.10	
Minor				
Non-latex aprons	-0.19	**	-0.11	~
Flush the eyewash every week	-0.16	**	-0.18	*
Sink in classroom/lab	-0.16	**	-0.09	
Safety zones taped on floor	-0.13		-0.16	**
Non-skid strips and/or rubber matting near machines	-0.15	**	-0.12	~
Table saw type: SawStop	-0.07		-0.14	*

Note. Statistical associations were calculated as polychoric correlations in full analytic sample (n=718).
*** $p < 0.0001$, ** $p < 0.01$, * $p < 0.05$, ~ $p < 0.10$

Table 2

Prevalence of risk factors associated with accident occurrences over a five-year period

	None n=109	**≥1 Minor** n=384	**≥1 Major** n=225	**Overall** n=718
	%	%	%	%
Risk Factors				
Major				
Course with increased hazards	59	84	88	80
>25% class time doing hands-on activities	84	92	96	91
Moderate				
Facility with a lab area	62	87	92	83
Minor				
Independent student use of table saw^	18	37	44	35
Carpet in lab area	10	12	8	12

Note. Overall = percentage of participants among the full sample who reported having the risk factor. ^ = based only on the number of participants that reported having a table saw in their lab (n = 469).

Table 3

Prevalence of protective factors associated with accident occurrences over a five-year period

	None n=109	**No Minor** n=110	**No Major** n=493	**Overall** n=718
	%	%	%	%
Protective Factors				
Major				
Dust collection system connected directly to equipment	36	36	57	64
Circuit breakers tripped in last 12 months	13	14	22	28
Safety glasses w/ side shields for every student	66	66	79	83
Moderate				
Separate finishing/chemical storage room	87	87	81	83
Fire extinguisher within 25 feet	74	75	83	86
Ear protection available for every student	32	33	44	49
Non-latex gloves available for every study	33	33	51	55
Master shut offs for electricity, gas, and water	49	49	57	61
GFCI Outlets	46	46	59	61
Lockable flammables cabinets	47	47	64	67
Lockable tool storage cabinets	66	66	76	78
Minor				
Non-latex aprons	27	26	37	39
Flushed the eyewash every week*	32	32	34	36
Sink in classroom/lab	63	63	74	76
Safety zones taped on floor	39	39	45	48
Non-skid strips and/or rubber matting near machines	17	17	25	27
Table saw type: SawStop^	38	38	53	56
Full Sample	15	85	31	100

Note. Overall = percentage of participants among the full sample who reported having the protective factor. * = based only on the number of participants that reported having a plumbed eyewash in their lab (n = 341). ^ = based only on the number of participants that reported having a table saw in their lab (n = 469).