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Accident Occurrences and Safety Issues Reported by Mid-Atlantic P-12 Engineering Educators

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Abstract

Laboratory safety poses inherent legal and ethical responsibilities that all engineering education programs in the United States (U.S.) must address. However, developing safer habits in the creation and testing of engineering design solutions starts long before students enter post-secondary engineering education programs. P-12 engineering education programs are a critical partner to develop greater safety awareness and safer habits among prospective engineers and our future workforce. This research utilized data from a national safety study involving 718 P-12 engineering educators from 42 U.S. states, specifically focusing on the subsample of 117 teachers from middle Atlantic (mid-Atlantic) states. Analyses found mid-Atlantic P-12 engineering educators reported a significantly higher rate of accident occurrences during a five year span in comparison to educators in other regions of the U.S. Further analyses identified numerous safety factors that were significantly associated with accident occurrences in mid-Atlantic P-12 engineering education courses. Additionally, significant differences were discovered regarding the types of items involved in accidents, and the occurrence of accidents within different types of P-12 engineering education courses. This research has direct implications for ensuring students entering post-secondary engineering education programs have a greater understanding of safety policies, practices, and ethics. Furthermore, identifying such gaps in safety practices at the P-12 level can assist higher education programs with focusing their safety instruction on the areas of greatest need for incoming engineering students. This can also help inform collaborate efforts among post-secondary engineering education programs, P-12 engineering education programs, and industry partners to address gaps in safety relative to engineering instruction.

Introduction

Safety has been a critical component of P-12 engineering education programs for decades as evidenced by its longstanding inclusion in curriculum plans and academic standards dating back to early manual arts and industrial arts programs (which later transitioned to technology education, and most recently technology and engineering education) [1]. Regardless of educational reforms, curricular shifts, and technological advances over the past century, safety in P-12 engineering education programs has remained relevant and is applicable to modern interdisciplinary learning environments where engineering learning is occurring, "The wood shop of the past is now seeing new life in makerspaces that cut across various media (e.g., sewing, metalworking, woodworking, electronics, etc.) with state-of-the-art tools and resources" (p. 868) [2]. Although the emergence of new technologies and processes has spawned improved safety features and protocols, there are potential hazards and health/safety risks associated with current tools/equipment and facilities that provide opportunities for students to create solutions to engineering design challenges. As described by Haynie [3], the tools/equipment in today's P-12 engineering education labs may appear much smaller and safer than the behemoth industrial machines found in shop classes during the manual arts and industrial arts eras; however, modern tools/equipment can be just as dangerous if not used properly. As P-12 educators seek to provide increased opportunities to engage students in engineering design experiences and develop a more technologically and engineering literate society [4], safety must remain at the core of all engineering education instructional efforts [1]. This is reflected in the current P-12 engineering education standards [4], *Standards for Technological and Engineering Literacy*, which place a strong emphasis on safety throughout the standards, practices, and context areas [5, 6]. Emphasizing safety during students' design and fabrication decisions provides important implications for improving young worker safety, safety in the workplace, and the safety awareness of students entering higher education engineering programs [7, 8].

Background

The inclusion of engineering content and practices in the *Next Generation Science Standards* (NGSS) in 2014 raised concerns from professional P-12 science and engineering educator associations. This included concerns about the increased safety hazards and resulting health and safety risks that science educators would need to be prepared to address when tasked with delivering hands-on engineering instruction [8, 9]. Conversely, graduates from most P-12 engineering teacher preparation programs complete coursework covering facility design and safety, safer pedagogical methods, and supervision of P-12 engineering lab activities [10]. However, with the growing shortage of highly qualified P-12 engineering educators, there has been an increasing number of teachers entering the profession through alternative licensure, which does not always require the completion of safety coursework like traditional P-12 engineering teacher preparation programs [9, 11]. This can present costly legal and safety issues for P-12 educators, administrators and school systems [9].

In addition to the legal issues resulting from inadequate teacher preparation and safety training, the literature has documented a severe lack of safety in various aspects relative to P-12 engineering education [7]. Specifically, Love et al. [9] highlighted the lack of improvement in P-12 engineering education related safety issues reported in studies from 2002 through 2022. Furthermore, a recent national P-12 engineering education safety study published by the International Technology and Engineering Educators Association (ITEEA) in collaboration with the American Society for Engineering Education (ASEE) and the National Science Education Leadership Association (NSELA) provided a comprehensive overview of the status of safety in P-12 engineering education programs across the U.S. [7]. This study involved 718 educators from 42 states who were teaching a variety of P-12 engineering courses. While providing national averages, the study also reported descriptive statistics according to geographic region. In comparison to other regions in the U.S., it was found that middle Atlantic (mid-Atlantic) schools had:

- A <u>higher percentage</u> of participants with a bachelor's degree in technology and engineering education, participants who believed they had a sufficient budget for safety needs, schools that conducted annual safety inspections, master shut offs accessible for electricity/gas/water, and finishing or chemical storage rooms with lockable flammables cabinets.
- A <u>lower percentage</u> of classes with enrollments/occupancy loads exceeding 24 students, participants who had a comprehensive safety training experience, schools with a district safety policy and PPE policy, safety zones taped on the floor around potentially hazardous equipment, fully stocked first-aid kits in their lab, eyewash stations in their lab, and participants who required students to always wear appropriately rated safety glasses with side shields or indirectly vented chemical splash goggles (meeting the ANSI/ISEA Z87.1 D3 standard) during lab activities.

Beyond the aforementioned regional and national findings, Love and Roy also published descriptive results specific to each mid-Atlantic state [12]. Moreover, analyses were conducted to further examine the responses of the 67 participating P-12 engineering teachers working in Pennsylvania school districts [13]. Similar analyses were conducted with data from the full national sample [8], identifying 17 protective factors (e.g., safety zones taped on the floor near potentially hazardous equipment) and eight risk factors (e.g., percentage of class time spent doing hands-on lab activities) that were significantly correlated with accident occurrences in P-12 engineering education courses. Moreover, analyses revealed findings with important implications for occupancy load and safety training in engineering education (Figure 1). These studies provided valuable foundational data that was missing from the literature on P-12 engineering education.

Figure 1

- P-12 engineering classes with enrollments exceeding 24 students were ***48% more likely*** to have had an accident occur [8].
- Educators who had comprehensive safety training were ***49% less likely*** to have had an accident occur in the P-12 engineering courses they taught [8].

Rationale and Research Questions

It is evident from the literature that there is a need to improve safety awareness, professional practices, and facilities involved with P-12 engineering education. While previous studies provided much needed safety data and recommendations from a national perspective, they also highlighted noticeable differences between regions in the U.S. (e.g., types of P-12 engineering courses taught) [7]. Further statistical analyses were recommended to examine safety differences more closely according to U.S. region [8]. Therefore, this study was conducted to investigate how safety factors related to mid-Atlantic P-12 engineering education differed from other regions of the U.S. Furthermore, this study sought to identify safety factors that were significantly associated with accident occurrences in mid-Atlantic P-12 engineering courses to provide safer instructional and learning experiences. The following research questions guided this study:

RQ1: To what extent do accident rates in P-12 engineering education courses differ between the mid-Atlantic region and other regions of the U.S.?
RQ2: What safety factors are significantly associated with accident rates in mid-Atlantic P-12 engineering education courses?
RQ3: To what extent do the items involved with accidents in P-12 engineering education courses differ between the mid-Atlantic region and other regions of the U.S.?
RQ4: To what extent do accident rates differ according to the focus P-12 mid-Atlantic engineering education courses?

Methods

This study analyzed data collected from the Technology and Engineering Education - Facilities and Safety Survey (TEE-FASS) [7]. The TEE-FASS consists of series of demographic and Likert-scale questions related to participant demographics, experience, teaching conditions, facility characteristics, safety training, safety practices, and accidents. The instrument collected mostly nominal and ordinal data to make it more user-friendly due to the large volume of questions and the type of information teachers had to recall (e.g., how many accidents occurred in their courses within the past five years). Within the context of this study, the term accident refers to water or chemical spills, slipping/tripping, broken glass, excessive fumes, small fires, projectiles, or other accidents that occurred during P-12 engineering course activities that may or may not have required medical attention from a school nurse or doctor. The link to the TEE-FASS was advertised by national and state P-12 engineering educator associations and yielded responses from 718 educators in 42 U.S. states. Among those 718 P-12 educators teaching engineering concepts, 117 taught in mid-Atlantic states (New Jersey, n = 28; New York, n = 22; and Pennsylvania, n = 67). More information about the reliability and validity measures of the TEE-FASS are described by Love et al. [8], and the full instrument can be accessed from Love and Roy [7].

Participants

Table 1 displays key demographic information about the full national sample and participants from the mid-Atlantic subsample. Both the national sample and mid-Atlantic subsample were predominantly male, White, taught secondary level P-12 engineering education courses, and had more than eight years of teaching experience. In comparison to the national sample, a greater percentage of mid-Atlantic participants were certified by their state's Department of Education to teach P-12 technology and engineering (T&E) education. Additional demographic information about the national sample and the mid-Atlantic participants is provided by Love and Roy [7].

Table 1

Participant Demographics

Characteristic	U. S. n = 718	M-A n = 117
Gender		
Male	74%	74%
Female	26%	26%
Ethnicity		
White	90%	94%
Bachelor's Degree Area		
T&E education	30%	42%
Professional engineering field	7%	6%
State P-12 engineering teaching certification	78%	87%
Grade Level Taught		
6-8	29%	30%
9-12	55%	53%
6-12	11%	7%
Years of P-12 teaching experience		
0-8 years	30%	24%
9-25 years	48%	58%
>26 years	23%	18%

Note. T&E = technology and engineering education; M-A = mid-Atlantic.

Results

Research Question 1

The first research question examined if there was a significant difference in accident rates between the mid-Atlantic region and other regions of the U.S. Respondents provided information about accident rates as ordinal responses (e.g., How many accidents occurred within the past five years? Response choices: 0, 1-5, 6-10, 11-15, or >15). Percentages were provided to help display the occurrence of accidents reported in the mid-Atlantic region in comparison to the rest of the U.S. (Table 2). These descriptive statistics indicate the mid-Atlantic region had a higher percentage of accidents in various occurrence categories. This led the researcher to hypothesize that there was a significantly higher occurrence of accidents in the mid-Atlantic region.

Table 2

Accident Occurrences Over a Five-Year Span

Region(s)	Number of Accidents 0 (%)	1-5 (%)	6-10 (%)	11-15 (%)	>15 (%)
Mid-Atlantic	9	45	20	16	10
Rest of the U.S.	17	49	18	9	7

Note. Mid-Atlantic n = 117, Rest of U.S. n = 601

Next, a Mann-Whitney U test was conducted to examine if there was a significant difference between the number of accident occurrences in the mid-Atlantic region compared to the rest of the U.S. The Mann-Whitney U analysis was deemed suitable to test for significant differences among two samples with ordinal (accident occurrence categories = 0-4) and nominal (binary mid-Atlantic region or rest of the U.S.) data. This type of analysis tests for the mean difference in rank of responses between two independent groups [14]. This analysis revealed a significantly greater number of accidents had occurred in the mid-Atlantic region over a five-year period (Table 3).

Table 3

Mann-Whitney U test for Accident Occurrences Over a Five-Year Span

Region (s)	Median	Mean Rank	U	z	*p*
Mid-Atlantic	1.0	383.82	32313.5	-2.222	0.026*
Rest of U.S.	1.0	354.77			

Note. Mid-Atlantic n = 117, Rest of U.S. n = 601, * = $p < 0.05$

Research Question 2

After examining differences in accident occurrences according to region, the second research question investigated what safety factors were significantly associated with accidents that occurred in mid-Atlantic P-12 engineering education courses. Using a similar method as Love et al. [8], exploratory correlational analyses were conducted to estimate the independent associations of numerous safety factors reported in the TEE-FASS with the occurrence of accidents over a five-year period. Associations were estimated as polychoric correlations. The polychoric correlation coefficient is an alternative to the Pearson *r*, which is used when variables represent a continuous measure but the data is organized in an ordinal manner (i.e., accident occurrence categories) [15]. The p-value for the likelihood ratio test was reported with the polychoric correlation coefficient for each safety factor (Table 4). These analyses revealed the direction of the correlations, which was reported in Table 4 as risk factors (positive correlation) or protective factors (negative correlation). Five risk factors and 20 protective factors were found to be significantly associated with reported accident occurrences. These correlations indicate that as a risk factor was present (e.g., a binary variable of 0 indicating their facility did not include/was not connected to a laboratory, or a 1 indicating they did have a laboratory facility) or as a risk factor increased (e.g., ordinal responses about the net square footage in their facility), the number of reported accidents also increased. Protective factors indicated that as the safety factor was present or increased, the number of reported accidents decreased. Due to the volume of safety factor questions included in the TEE-FASS, only those factors which were found to be statistically significant are reported in Table 4.

Table 4

Polychoric Correlations of Safety Factors Associated with Accident Occurrences Over a Five-Year Span in mid-Atlantic P-12 Engineering Courses

Significant Safety Factors	Accident Occurrences	
	ρ	*p*
Risk Factors		
Lab in/connected to facility	0.66	***
Percentage of class time doing hands-on activities	0.45	***
Room square footage	0.40	***
Separate finishing room	0.41	**
Course enrollment >24	0.34	*
Protective Factors		
Safety glasses w/ side shields for every student	-0.59	***
Master shut offs for electricity, gas, and water	-0.51	***
Fire extinguisher within 25 feet of lab activity area	-0.49	**
Dust collection system connected directly to equipment	-0.34	**
Flush eyewash each week	-0.45	**
Lockable storage cabinet(s)	-0.43	**
Safety tests required for all students before any lab activities^	-0.42	**
Lockable flammables cabinet(s)	-0.38	**
Supervised student safety demonstrations after completing safety tests^	-0.37	**
Eyewash within 25 feet of lab activity area	-0.35	**
Non-latex aprons	-0.34	**
Sink in classroom/lab	-0.30	*
Circuit breakers tripped in last 12 months	-0.29	*
Completed an undergraduate course on safer teaching^ methods in labs	-0.28	*
Table saw type: SawStop	-0.26	*
Safety questions included on unit quizzes^	-0.25	*
Require students to always secure long hair^	-0.27	~
Adequate number of GFCI outlets	-0.24	~
Non-latex gloves available for every student	-0.22	~
Require students to always secure loose jewelry and sleeves^	-0.22	~

Note. ^ = Significant factor in this study but was not a significant factor in national analyses [7]. *** = $p < 0.0001$, ** = $p < 0.01$, * = $p < 0.05$, ~ = $p < 0.10$.

Research Question 3

While RQ2 examined associations between safety factors and accident occurrences in mid-Atlantic P-12 engineering courses, it did not investigate the tools/items that teachers reported were involved with accidents. Therefore, RQ3 examined if there was a significant difference between items involved with accidents in P-12 engineering education courses in the mid-Atlantic region compared to other regions of the U.S. Mann-Whitney U analyses were used again due to the nominal (binary item involved or not involved, binary mid-Atlantic region or rest of the U.S.) nature of participants' responses. These tests revealed equipment/machinery (drill press, computer numerical control [CNC] equipment, miter saw, belt/disc sander, etc.) was the only item that significantly differed between the mid-Atlantic and other regions of the U.S. Equipment/machinery was involved in a significantly greater number of P-12 engineering education accidents in the mid-Atlantic region compared to other regions (Table 5).

Table 5

Mann-Whitney U tests for Items Involved in Accidents over a Five-Year Span

Item and Region	Involved n (%)	Median	Mean Rank	U	z	*p*
Hot Glue Guns						
Mid-Atlantic	46 (39)	0	365.65	34439.5	-0.418	0.676
Rest of U.S.	224 (37)	0	358.30			
Equipment/Machinery						
Mid-Atlantic	35 (30)	0	384.89	32187.5	-1.991	0.047*
Rest of U.S.	129 (22)	0	354.56			
Hand/Power Tools						
Mid-Atlantic	25 (21)	0	361.71	34900.0	-0.179	0.858
Rest of U.S.	124 (21)	0	359.07			
Projectiles						
Mid-Atlantic	19 (16)	0	367.80	34187.5	-0.789	0.430
Rest of U.S.	81 (14)	0	357.88			
Spills or Splashes						
Mid-Atlantic	21 (18)	0	370.94	33820.5	-1.061	0.289
Rest of U.S.	85 (14)	0	357.27			
Fumes						
Mid-Atlantic	12 (10)	0	368.82	34068.0	-1.153	0.249
Rest of U.S.	43 (7)	0	357.69			
Broken Glass						
Mid-Atlantic	11 (9)	0	370.75	33842.0	-1.528	0.127
Rest of U.S.	34 (6)	0	357.31			

Note. Involved = number of participants who reported this item was involved in an accident, Mid-Atlantic total n = 117, Rest of U.S. total n = 601, * = $p < 0.05$

Research Question 4

After examining items involved in accidents, additional questions arose about the types of P-12 engineering education courses taught and potential differences in accident occurrences according to course focus. Therefore, the fourth and final research question investigated if there was a significant difference in the number of accidents that occurred within the various P-12 engineering education courses taught in the mid-Atlantic region. Table 6 provides percentages to help display the range of accidents reported according to course focus. These descriptive statistics demonstrate that power, energy, transportation, and electronics (PETE) courses had the lowest percentage of participants reporting 11 or more accidents. Manufacturing and construction courses experienced the greatest percentage of accident occurrences in the 6-10, 11-

15, and >15 categories. These descriptive statistics led the researcher to hypothesize that there was a difference in accident occurrences according to P-12 engineering course focus.

Table 6

Percentage of Accident Occurrences in mid-Atlantic P-12 Engineering Courses Over a Five-Year Span

Course	Accident Occurrences				
	0 (%)	1-5 (%)	6-10 (%)	11-15 (%)	>15 (%)
Eng. Design	4 (7)	29 (50)	13 (22)	8 (14)	4 (7)
Man. & Const.	1 (4)	8 (29)	7 (25)	8 (29)	4 (14)
Comm. & Graphics	2 (13)	8 (50)	0 (0)	3 (19)	3 (19)
PETE	3 (20)	8 (53)	3 (20)	0 (0)	1 (7)

Note. Note. Eng. design = Engineering design and pre-engineering courses (n = 58); Man. & const. = Manufacturing and construction courses (n = 28); Comm. & graphics = Communications and graphic design courses (e.g., CAD) (n = 16); PETE = Power, energy, and transportation courses (n = 15); Total n = 117.

Mann-Whitney U tests were used to further examine the differences among courses due to the ordinal (accident occurrence categories = 0-4) and nominal (binary course focus) responses from participants. These analyses revealed that manufacturing and construction courses had a significantly higher number of accidents than other courses, and PETE courses had a significantly lower number of accidents in comparison to other courses. Engineering design, and communications and graphics courses did not have significantly more or less accident occurrences than other courses (Table 7).

Table 7

Mann-Whitney U tests for Accident Occurrences in P-12 mid-Atlantic Engineering Courses Over a Five-Year Span

Course	Median	Mean Rank	U	z	*p*
Eng. Design	1	56.62	1573.0	-0.796	0.426
Other Courses	1	61.34			
Man. & Const.	2	72.88	857.5	-2.626	0.009*
Other Courses	1	54.63			
Comm. & Graphics	1	58.09	793.5	-0.122	0.903
Other Courses	1	59.14			
PETE	1	43.27	529.0	-2.035	0.042*
Other Courses	1	61.31			

Note. Eng. design = Engineering design and pre-engineering courses (n = 58); Man. & const. = Manufacturing and construction courses (n = 28); Comm. & graphics = Communications and graphic design courses (e.g., CAD) (n = 16); PETE = Power, energy, and transportation courses (n = 15); Total n = 117; * = $p < 0.05$

Discussion

While this study provides important implications for improving the safety in P-12 engineering education courses, it has some limitations. Although there was a high percentage of white and male participants, this aligns with demographic findings from other national P-12 engineering education studies [16]. Additionally, results were voluntarily self-reported, and it is unknown if teachers who responded had an increased interest in participating due to safety issues they experienced and felt strongly about reporting. Moreover, the TEE-FAS collected information about accident occurrences as ordinal data instead of continuous data. This warranted the use of polychoric correlation analyses similar to the methods used by Love et al. [8] when analyzing results from the full national sample. While these analyses helped identify items associated with accident occurrences, caution must be exercised when interpreting the results. These correlational analyses do not indicate causation, rather they highlight a relationship exists between the specified safety factors and accident occurrences. Knowing what factors have a significant association with accident occurrences, either in a positive direction (risk factor) or negative direction (protective factor), can help raise awareness regarding potential safety hazards and resulting health and safety risks that may pose greater risks and need to be addressed to reduce the chance of accidents.

Research question one revealed that P-12 engineering courses in the mid-Atlantic region had a significantly higher occurrence of accidents in comparison to P-12 engineering courses taught in other regions of the U.S. This warranted further analyses to determine what was associated with accident occurrences in mid-Atlantic P-12 engineering courses to inform safety efforts. When examining what safety factors were significantly associated with accident occurrences, the results from the polychoric correlation analyses were similar to previous research examining the full national sample [8]. However, there were a few safety factors that emerged as significant in the mid-Atlantic region which were not found to be significant in the national study. Those protective factors included:

- Completion of an undergraduate course which taught safer teaching methods for overseeing lab-based P-12 engineering instruction.
- Safety tests always required for all students before participating in any lab activity.
- Supervised student safety demonstrations after viewing instructor demonstrations and passing safety tests.
- Safety questions included on quizzes throughout the course.
- Requiring students to always secure their long hair.
- Requiring students to always secure their loose jewelry and sleeves.

While many of the factors in Table 4 are required under mandated state or federal occupational health and safety plans in mid-Atlantic states (e.g., OSHA's Personal Protective Equipment Standards - 1910 Subpart I) they are also legally required under better professional safety practices. These state and federal safety plans would also apply to higher education engineering education laboratories in most cases (the plan that applies may depend on if an institution is public or private).

One interesting finding from this study was that having a separate finishing room was found to be a risk factor in this study, whereas in the national study [8] it was a protective factor. This may indicate that in the mid-Atlantic region, a separate finishing room (e.g., room with a paint booth) presented additional potential hazards/resulting health and safety risks, and required increased supervision for this space that was separate from other areas and potentially occupied by students. Furthermore, safety zones and non-skid strips taped on the floor near equipment were not found to be significant safety factors in this study but were significant in the national analyses. Some factors in Table 4 were found to have a stronger correlation with accident occurrences than other factors. While this does not suggest specific safety factors are more hazardous than others, it does highlight areas that may need additional attention to provide safer P-12 engineering instruction. Additional details about how safety factors relate to state and/or federal occupational health and safety regulations are provided by Love and Roy [7] and Love et al. [8].

Similar to the national results, hot glue guns were the most common item teachers reported as being involved with accident occurrences in the mid-Atlantic region. However, the Mann-Whitney U tests revealed that only equipment/machinery were involved in significantly more accidents than other items when comparing the mid-Atlantic to the rest of the U.S. This suggests that:

- P-12 engineering educators may need additional training and other support to emphasize safety related to equipment and machinery use.

The results from the fourth research question align with the findings regarding equipment machinery in RQ3. Given that manufacturing and construction courses were found to have significantly more accident occurrences than other courses, one would expect equipment and machinery which often used in those courses to also be involved with a significantly higher number of accidents. However, hand and power tools (cordless drill, soldering iron, etc.) which are often used in many P-12 engineering courses were not found to be involved with a significantly higher occurrence of accidents. Again, it should be noted that all items analyzed in RQ3 can be extremely dangerous without proper engineering controls, personal protective equipment (PPE), and safety practices.

One might hypothesize that manufacturing and construction courses would experience a greater number of accidents due to the increased risks associated with large equipment that is often utilized during these courses. However, one may also expect communications and graphics courses to have significantly less accident occurrences given the digital nature of technologies taught in these courses (computer aided drafting, digital photography, etc.). There was no significant difference between accident occurrences in communications and graphics courses and other courses. One explanation for this is that teachers may have selected communications and graphics as their main teaching focus but taught those courses within the context of electronics, construction, engineering design, or other areas. An interesting finding from RQ4 was the significantly lower occurrence of accidents in PETE courses. Additional research is needed to further explore the differences in accidents that occur in various P-12 engineering courses. While RQ4 does highlight differences in accidents according to course focus, it should be noted that almost every P-12 engineering course can have increased potential hazards/resulting health and safety risks without the use of appropriate engineering controls, better professional safety practices, and legal safety standards.

Conclusions

While this research focuses on safety specifically in P-12 engineering contexts, it does have direct implications for improving safety in post-secondary engineering education programs and the workforce. Students from P-12 engineering education programs will be matriculating into higher education programs and the workforce, carrying with them the safety knowledge and practices they learned during their P-12 experience. Post-secondary engineering education programs and industry partners hiring students in these areas should utilize the results from this study to inform areas (e.g., safety factors) where incoming students and young workers may need additional safety training and support. This could help address gaps in students' safety knowledge and practices, consequently reducing the odds of an accident. The findings from this study can also help inform collaborate efforts among post-secondary engineering education programs, P-12 engineering education programs, and industry partners to address the identified gaps in safety. Lastly, this research has direct implications for P-12 engineering educators, administrators, school districts, school district safety officers, chemical hygiene officers, and engineering teacher preparation programs to help make P-12 engineering teaching and learning experiences safer.

Recommendations

This research highlights that while there are similarities among regional and national P-12 engineering education safety findings, there may also be some slight differences unique to each region based on a variety of factors (e.g., prevalence of the types of engineering courses taught in specific regions). Further analyses examining differences related to accident occurrences within P-12 engineering courses in other regions of the U.S. are warranted to better inform engineering education programs. As recommended by Love et al. [8], this study examined differences in accident occurrences according to the types of items involved with accidents and the foci of P-12 engineering courses. However, further research is needed to examine if additional safety factors have an influence on these differences. The results from this study suggest that collaborative efforts like the following could help improve safety in engineering education:

- Post-secondary engineering educators, teacher preparation faculty, P-12 engineering educators, and occupational health and safety specialists should collaborate on future research and outreach initiatives to improve safety in engineering education.
- State departments of education, school districts, P-12 engineering educators, and engineering teacher preparation programs should consider the findings presented in this study to inform professional development efforts, safety training needs for instructors and students, and support required for safer engineering instruction.

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