Safety Awareness

Identifying a Need for Undergraduate Engineering Students

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Young engineering and science students often participate in technical design teams and class project teams during the academic year. At Missouri University of Science and Technology, Formula SAE race cars, ASCE Concrete Canoe, robotics competitions and aircraft designs are just a few examples of these opportunities (Student Design and Experiential Learning Center, 2014). To prepare for the competitions, students spend time in campus workshops where they encounter different types of hazardous and flammable materials, machines and other hazards. Similarly, students majoring in either engineering or science majors conduct lab experiments as part of their required academic curriculum. Because their safety training is often inadequate, these college students are exposed to numerous hazards.

IN BRIEF
- **Students with technical majors must take scientific laboratory courses and many apply their knowledge by engaging in various competitive technical design teams. This requires them to spend time in labs and/or workshops, which can be hazardous environments.**
- **The survey reported on here examines the safety training exposure and knowledge among students on technical competition teams.**
- **Upon earning their degrees, these students will become practicing engineers and scientists. Their safety awareness and attitude toward risk is often being formed while in college and will follow them into their professional careers.**

Over the past decade, concerns have grown about the frequency of academic laboratory incidents that have produced severe injuries and deaths. For example, a graduate student conducting a chemical lab at Texas Tech University lost three fingers, burned both his hands and face, and injured an eye in an explosion that destroyed the entire laboratory facility (CSB, 2010). A 23-year-old female student at UCLA died of second- and third-degree burns suffered while conducting a research experiment in a campus lab (Christensen, 2009). Another student died of asphyxiation due to neck compression when her hair caught in a lathe machine in Yale University's workshop (Henderson, Rosenfeld & Serna, 2012). Four students from the University of Missouri-Columbia were severely injured during a hydrogen explosion in June 2010 (CSB, 2010). Two University of Maryland students suffered first- and second-degree chemical burns as a result of a chemical explosion attributed to improper waste management (Kemsley, 2009).

Investigation reports of these incidents cite causes such as improper safety procedures, lack of training, improper training documentation and not wearing PPE (Kemsley, 2009). These events suggest that college students lack minimum safety awareness and training in safe work habits.

Literature Review

The U.S. workforce employed 19.5 million workers ages 16 to 24 in July 2012 (BLS, 2012). For the period from 1998 to 2007, the U.S. recorded 3.6 deaths per 100,000 young workers (BLS, 2012). Furthermore, 7.9 million nonfatal injuries involving members of the same age group were treated in emergency departments (CDC, 2010).

Researchers have found that young workers are at more risk than their older colleagues when it comes to workplace injuries (Breslin, Tompa, Zhao, et al., 2008; McCabe, Loughlin, Munteanu, et al., 2008; Salminen, 2004). Other studies show that young adults tend to exhibit higher *sensation seeking*, which

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is defined as pursuing intense experiences and the willingness to take different levels of risks to reach that experience (Zuckerman, 1979, 1994).

Numerous researchers have discussed the variables that account for such behavior in emerging adults; these include both cognitive and psychosocial factors (Steinberg & Cauffman, 1996). Researchers have posited various theories to explain risk-taking behavior in young adults and adolescents. These fall into three essential categories: 1) biological, based on hormonal effects, asynchronous pubertal timing or genetic predispositions; 2) psychological or cognitive deficiencies in self-esteem, cognitive immaturity or affective disequilibrium; and 3) environmental causes that focus on social influence related to family and peer interactions, or community and societal norms (DiClemente, Hansen & Ponton, 1995).

Psychological studies have explored potential causes of unsafe decision making within adolescent and college students (Laursen, 2009). Results show that the brain's frontal lobes contain all the neurological executive functions in the process of decision making—preparation, evaluating and historical referencing in terms of both long- and short-term memory (Johnson, Blum & Giedd, 2009). Laursen (2009) evaluated adolescent brain development, especially the frontal lobe, and states that brain "maturation" requires "opportunities to interact in group situations which facilitate concern for others, problem solving and responsible behavior" (p. 8). As a result, the frontal lobe establishes the ability to indicate and weigh potential consequences of any act to be executed, and this function is relatively slowly developing compared to adults (Laursen, 2009).

To protect laboratory users, and to avoid lawsuit claims for liability and negligence, universities should adhere to federal regulatory requirements related to laboratories. These include OSHA's HazCom (29 CFR 1910.1200) and Laboratory (29 CFR 1910.1450) standards, and EPA's Resource Conservation and Recovery Act (RCRA), which regulates both hazardous waste and air pollutants (Amherst College, 2014).

Campus environmental safety and health departments are typically the on-campus resource for regulatory compliance, hazardous waste management, laboratory and radiation safety, and safety program administration. American Chemical Society (2012) conducted comparative studies to examine existing laboratory safety procedures from different universities. Results indicated that university labs adhere to state laws and minimum OSHA and EPA requirements, which helps the institutions avoid liability from negligent behaviors.

Before supervising laboratory experiments, both laboratory technicians and/or graduate students complete safety training. This training aims to familiarize them with relevant regulations and appropriate safety guidelines. Training typically consists of classroom lectures or online videos, and topics include using safety data sheets (SDS), HazMat management, chemical waste tags, chemical compatibility and storage, spill response procedures, use of fire safety equipment and PPE (National Research Council, 2011).

Once trained, lab technicians and/or graduate students may supervise undergraduate students conducting curriculum laboratory experiments. Before any lab activities commence, students must complete a safety orientation seminar (in-person or video-based training), then sign a completion form or complete a questionnaire to be considered eligible to perform supervised lab tasks. Unfortunately, students typically lack the comprehension of minimal "risk management techniques that are designed to eliminate various potential dangers in the laboratory" since their training does not cover all topics related to lab safety (National Research Council, 2011, p. 3)

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Study Method

To measure safety training, knowledge and attitude of college students at Missouri University of Science and Technology, the research team conducted a survey based on the Goal Question Metric approach (Basili, Caldiera & Rombach, 1994). Survey goals were to determine the amount of training the students had on OSHA procedures; evaluate their knowledge and application of general safety procedures; and assess their safety attitude and consciousness (Table 1, p. 40).

Ultimately, a 23-item questionnaire was developed: five questions on safety training; six questions on knowledge of OSHA procedures; five questions on attitude toward safety in labs or workshops; two questions on their safety consciousness (self-assessed); and five demographic questions.

Study Results & Analysis

A total of 93 web-based questionnaires were returned by students participating in the university's competitive design teams. Among the study population, 68% of the respondents were male, 31% were female and 1% preferred not to answer. Most respondents were undergraduates (32% seniors, 25% juniors, 17% sophomores, 18% freshmen); the others were alumni (3%) and graduate students (3%). Among respondents, 95% of the students were majoring in engineering, and 95% were either involved in one or more design competition team in the present or past. When asked whether they had received any safety training during their academic years, 97% stated they were exposed to some safety training (e.g., OSHA 10-hour training, first-aid, CPR and AED training, high-school shop training).

Study Goal 1: Evaluate Safety Training

Students were asked if they received any formal safety training during their academic years. Response options were chemistry laboratory safety training, workshop safety training, safety engineering or similar classes offered on campus, and any other related form of education they might consider a safety course. Results indicated that less than 30% of respondents had any type of formal training. Most had been exposed to shop safety training, which is limited to certain types of equipment and,

Table 1
The Goal Question Metric Survey Model

Goals	Questions	Metrics
Evaluate the amount of safety training of Missouri S&T design team members	Have you been trained to use PPE?	•"No, never" •"Yes, no formal training" •"Yes, formal training" •"Can't remember"
	Have you been trained on how to prepare/understand lockout/tagout?	
	Have you been trained on using MSDS?	
	Have you been trained on machine guarding?	
	Have you been trained on evacuation from your workplace or lab(s) in case of an emergency?	
Evaluate the student design team members' safety knowledge	In which of the following situations are you required to wear safety glasses?	Percentage of correct response
	Lockout/tagout is required when? (check all that apply)	
	Locks should always stay on the equipment during the shift change? True or false	
	When working in a workshop/lab, when do you use MSDS? (check all the apply)	
	Which statements are true about machine guarding?	
	Check all that apply regarding emergency evacuation	
Evaluate the student design team members' safety attitude	In situations where safety glasses are required, how often do you wear them?	Likert scale and open-ended discussion
	Do you refer to the MSDS whenever a chemical or a HazMat is spilled?	
	How often do you check if machine guards are installed on the machine you are about to use?	
	In case of an emergency, how often would you follow the instructions written for the emergency action plan?	
	If you feel that PPE is not necessary when working in workshops and labs. Please discuss why below.	
Evaluate the student design team members' safety consciousness	How safety conscious are you?	Likert scale and open-ended discussion

thus, does not necessarily include OSHA's recommended five domains of safety. This suggests that most of these young prospective engineers have been working in the labs or workshops without proper training.

Study Goal 2: Evaluate Safety Knowledge

Respondents were asked about workshop and laboratory safety procedures. The question was designed to assess students' knowledge of SDS, facility evacuation procedures, PPE and machine guarding requirements. Only 47% of respondents were able to identify the safety requirements for laboratory or workshop task execution. As a result, the students do not know safety work procedures, do not know how to properly respond to a HazMat spill, and/or do not know the proper evacuation route and assembly point.

Study Goal 3: Evaluate Safety Attitude

When asked to describe their attitude toward safety, 70% of participants did not answer, while the remaining 30% indicated that they follow safety procedures while in a workshop or lab working on their projects. Of these, 73% said they follow the procedures occasionally, while the remaining 27% adhere to the procedures only when mandated. This indicates that the students underestimate the potential consequences of violating procedures. Furthermore, when unsupervised, they tend to take shortcuts to perform the required experiments. This indicates that students lack the proper safety attitude about executing laboratory assignments in positive, safe way.

Study Goal 4: Evaluate Safety Consciousness

Respondents were asked to evaluate their overall safety consciousness. Results showed that 58% of the respondents deem themselves safety conscious, with 25% saying they are very conscious. However, most participant indicated that they are neutral when it comes to evaluating themselves in terms of overall safety consciousness.

Utilizing Best Practices

To address the identified need for greater safety in workshops and labs, practices from industry may offer some guidance. For example, the petroleum and process industries are committed to zero incidents and do not tolerate negligence (Vinnem, Hestad, Kvaløy, et al., 2010). These industries use training cards to indicate that a worker has successfully passed accredited safety program modules needed to perform a required task (API, 2014). The program aims to recognize those who are competent to execute the required tasks according to established standards and procedures (API, 2014).

The University of Reading uses a permit-to-work approach for its labs and workshops (Health and Safety Services, 2014). Its form is used to identify all hazards on the premises and certifies, to the lab or workshop user, that all safety precautions have been considered; it also includes recommendations for PPE or related safety measures. This document enables supervisors to manage access to their facilities and identify hazards that users may encounter while performing their routine activities (Health and Safety Services, 2014).

Conclusion

The neglect of minimum safety requirements in machine shops or laboratories can result in avoidable incidents and losses. The science/engineering undergraduate students surveyed for this article had received only informal safety training prior to participating in either laboratory experiments or working in the design teams' machine shops. Such training is often ineffective, and it does little to ensure a positive safety attitude or improve safety performance.

In addition, the survey showed that respondents' knowledge of five domains of OSHA guidelines (i.e., PPE, lockout/tagout, SDS, machine guarding, emergency action plan) was insufficient. Lack of knowledge in these areas can cause undesired consequences when incidents occur and when students fail to follow proper safety guidelines. In addition, this limited knowledge affects their understanding of the risks associated with their projects as well as their overall attitude toward safety. Essentially, students underestimate the potential consequences when a positive safety attitude is not part of their work ethic.

Utilizing an administrative system, such as training cards or a permit-to-work system, can add layers of defense and safeguards that can mitigate potential consequences (Altabbakh, Murray, Grantham, et al., 2013). Holding both lab and/or workshop supervisors and students accountable for executing tasks safely can raise safety cautiousness and improve understanding of potential failure consequences.

It is essential to help novice engineers establish their personal safety culture during their college years. Serious chemical or laboratory incidents are often deemed to be the result of a weak or deficient safety culture (Committee on Chemical Safety, 2012). Implementing an effective safety culture will protect all involved and enhance students' safety awareness. Industry would benefit from a new breed of engineers and scientists with safety culture and awareness ingrained in them. Creating a safety-aware environment and exposing them to real incident scenarios will direct their mind-set toward risk management. Providing this safety training in college can positively shape the safety attitude that they will carry with them into the work environment. Developing this commitment to safety early in these future professionals' lives can have a great impact on safety over time. **PS**

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