2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #39484

Lab Safety Awareness in Incident and Near-miss Reporting by Students Participating in Engineering Societies: A Case Study

Audrey Erin Concepcion
Ryan Hekker
Dr. Ean H. Ng, Oregon State University

Ean H. Ng is an assistant professor of Industrial Engineering at Oregon State University. She received her Ph.D. in Systems and Engineering Management from Texas Tech University. Her research interests include engineering economic analysis, high reliability organization, safety engineering, peer effects in workplace safety, and performance measurement.

Chukwudiebube Atagbuzia
Thomas L Doyle, Oregon State University
Jenette K Paul, Oregon State University

Lab Safety Awareness in Incident and Near-miss Reporting by Students Participating in Engineering Societies: A Case Study

Academic laboratory safety has gained considerable attention from researchers and research institution administrators since several high-profile incidents in the late 2000's. Another part of student learning in engineering, though informal, occurs in co-curricular activity such as engineering societies and team competitions where students conduct hands-on activities to achieve certain objectives, usually with minimal (if any) authoritative figures in presence. The safety aspect of these co-curricular activities remains unexamined in research literature. Even though students were taught and practiced safety procedures and behavior during formal classroom labs, whether the safety knowledge and practices transfer to the informal setting remains unknown.

The objective of this preliminary study is to examine students' safety knowledge and behavior while conducting these hands-on activities without formal supervision. The study employs a qualitative approach which begins with an informational form completed by student society leaders to identify student societies that involve hazardous activities and subsequent in-depth interviews with societies to assess their safety approaches. The results show that there is a knowledge gap among the students in terms of what events qualify as an incident or a near-miss, and the need to report incidents and near-misses that occur during their society's activities. In addition to the lack of knowledge on incidents and near-misses, the fear of punishment and the unease to speak up when they see unsafe behavior exhibited by their peers also contribute to the lack of reporting.

Even though lab safety knowledge is taught and practiced in lab-based courses, the case study results show that students that use labs for student society activities may need consistent reminders and nudges to practice safe behavior and be diligent in reporting safety incidents and near-misses. In addition, students may need encouragement and empowerment during formal lab-courses to speak up when they observe unsafe practices, as they might have been conditioned to rely on authority figures (instructor or TA) in lab-courses to monitor and verbally remind students to use proper safety procedures and practices.

Introduction

Since the tragic lab incident at UCLA in 2008 that resulted in the death of a graduate student, the 2010 explosion at Texas Tech University that injured a graduate student and a professor, and several high-profile accidents in academic laboratories, academic lab safety has gained considerable attention [1]. Since these high-profile incidents, academic lab safety, specifically chemical lab safety, has spurred a number of publications, programs, and risk management guidelines and policies on academic lab safety and promoting safety culture in academic labs (e.g. American Chemical Society [2], American Institute of Chemical Engineers [3], National Academies [4], Association of Public & Land-Grant Universities [5], and examples of research articles [1], [6], [7], [8])

A bibliometric study on academic lab safety showed that there is an increase in academic lab safety research, though it is still a minority research field within the larger safety research domain [8]. A review and critique study on academic lab research found that these efforts have been insufficient as their study showed that there has been a lack of data on the changes in academic communities' safety attitudes and behaviors, as well as the need for leadership commitment to safety from the research institutions [1]. Another study surveyed faculty at a medium-sized, research active, private institute and found that there is a weak safety culture within academia [7].

Engineering student societies serve as an extension of a student's formal learning from the theory and lab-based classes into actual practice. Studies on safety in academic settings generally focus on academic research laboratories with graduate students and postdoctoral researchers (e.g. [9], [10], [11]) or focus on formal learning such as laboratory sessions or classroom teaching (e.g. [12], [13]). None of the existing studies we found in the literature focus on university undergraduate student safety practices in co-curricular activities such as engineering clubs and engineering team competitions (e.g., SAE, robotics, over-clocking, concrete canoe). In addition to lab safety, co-curricular activities pose different challenges because these activities are usually conducted through voluntary basis, thus, the member turnover rate is high, club leadership change is rather frequent, and occurrence of knowledge-sharing, especially on safety knowledge, is questionable. As these activities are usually conducted outside of formal labs and thus do not usually have a formal authority figure in presence, students must monitor themselves and each other with regards to safety practices.

Following industry workplace safety standard, each engineering student society should conduct a formal risk assessment at the beginning of each academic year, and develop their lab safety procedure based on the risk assessment. In contrast to industry workplace safety standard, engineering student society lab safety generally consists of two important components: (1) prevention through the proper use of equipment/methods/procedures and personal protective equipment (PPE), and (2) reporting of any incidents and near-miss events to facilitate the revision of the procedure and removal of any potential hazards. Even though lab safety knowledge and practice are taught and emphasized during lab-classes, students do not necessarily transfer their lab safety knowledge and practice into their engineering club activities and/or apply the same level of care in the prevention and diligence in reporting.

Motivation

Oregon State University (OSU) Department of Environmental, Health, and Safety (EH&S) noticed that near-miss reporting from student club activities has been non-existent. A near-miss is defined as an unplanned event that did not result in injury, illness, or damage, but had the potential to do so [9]. A near-miss has been recognized as a leading indicator in safety management and as an opportunity to improve overall workplace safety [10]. Focusing on OSU College of Engineering (COE), there have been zero near-misses reported since 2018 from student societies, and OSU EH&S was interested in identifying the root cause of the lack of near-miss reporting.

OSU COE student societies consist of student chapters of professional engineering societies, as well as societies that form to participate in national and international student engineering team competitions. At OSU, a student society is considered 'recognized' by the COE if the society is officially registered with OSU's Associated Students of OSU (a student-governed entity that represents and advocates for students in OSU's shared governance) and the society designates the COE as the ‘home’. This study examined the student societies that were recognized by the COE only, which excluded (1) self-organized student activities that might/might not operate within the campus, and (2) student societies that are recognized by other colleges within OSU, such as colleges of science/forestry/agriculture/veterinary medicine, where safety concerns are inherent in their student societies’ activities.

This study was conducted as a senior capstone project by a team of four industrial engineering and one mechanical engineering senior students. The capstone senior project spanned two quarters, for a total of 22 weeks, and was sponsored by the OSU Department of EH&S, advised by an industrial engineering faculty, and assisted by a PhD student in industrial engineering. The capstone senior project focused on identifying the root cause of the lack of near-miss reporting among student societies within the COE through the development of research instruments and preliminary data collection and analysis.

Qualitative Approach of Current Study

Existing studies on academic laboratory safety either focus on formal learning settings (see [12], [13]) or focus on research laboratories (see [9], [10], [11]). The participants’ characteristics in existing studies that focus on formal learning settings or research laboratories differ from the engineering student societies’ student population in two major characteristics: (1) turnover rate – student population in formal classroom settings and research laboratories are relatively stable over the term or academic year, whereas in engineering student societies, students participate on a voluntary basis and attendance is not always mandatory; (2) authority figures – there are clear authority figures in formal classroom settings and research laboratories, whereas engineering student societies are organized and managed mainly by students. Even though student societies usually have at least one faculty advisor, the involvement of faculty advisors varies significantly across the board. The two distinct characteristics of the engineering student societies’ population made it infeasible for us to employ existing methods to study the student safety in informal learning settings through student societies.

As we did not find any existing studies that focus on informal learning through co-curricular activities, we employed a qualitative approach to establish the current state of student safety in informal learning settings. An informational form and request for society safety documentation was distributed to all 46 student societies that were recognized by the OSU COE. From the responses from student societies’ leaders, student societies’ activities that involve hazards were identified and became the focus of the interview. Once the interview concluded, the responses were reviewed and coded by two undergraduate students and one graduate student to identify themes within the responses. The coded responses were analyzed and grounded in existing educational theory to provide further insights on the current state of students’ safety approach.

Methodology

To identify student societies whose activities involve hazards, an online form was distributed to collect information from all 46 student societies. Each student society was also asked to share with us any safety documentation they may use. Based on the online form information and safety document analysis, we asked for volunteers from societies that dealt with hazards to take part in an interview assessing their knowledge, perceptions, and attitudes towards safety and near-miss events. As we employed a qualitative approach to our study, triangulation was necessary in order to assess the validity of the information collected. We used the online form submissions, safety documentation, and interview responses to confirm our findings.

Online Form for Preliminary Data Collection: We developed an online form in Qualtrics to collect preliminary information on societies that routinely perform potentially hazardous activities. We administered the online form both via email request and in person at the Engineering Student Council General Body Meeting (a meeting held twice each academic quarter that a leadership representative from each COE society is required to attend), requesting a single response from a leadership member of each society. We used responses from the online form to identify societies that reported at least one hazard and requested volunteers for live interviews from those societies. The form included the following information: (1) organization name, (2) primary email address associated with the organization, (3) where does your organization meet (4) how many active members does your organization have, and (5) how frequently does this organization meet.

Within the online form, we provided responders with definitions for 11 hazards identified by the OSU Department of EH&S, to which they could select "Yes", indicating that their club activity involves that particular hazard, "No", or "Not Sure". The 11 types of hazards included are as follows:

1. Chemical hazards
2. Biological hazards
3. Slip, trip, or fall hazards
4. Radiation, light, or laser hazards
5. Machine hazards
6. Confined space hazards
7. Noise hazards
8. Temperature hazards
9. Electrical hazards
10. Vibration hazards
11. Sunlight or ultraviolet (UV) ray hazards

The final question asked responders to describe any additional hazards not included in the above list that their society deals with, if applicable.

After each society completed the online form, we validated the accuracy of the submission through review of each society's website, social media, and consultation with OSU EH&S on their knowledge of the society's routine activity. Any society that we identified as having potential safety hazards despite not self-reporting was also contacted for interview volunteers. This validation process provided us with insight into whether the society's leader(s) who submitted the form could identify potentially hazardous activities in their regular society activities.

Document Analysis: We reached out directly to society leaders requesting any safety documentation the organization might have. This enabled us to gain a better understanding of the society's prioritization of safety based on the robustness of documentation provided. From the document analysis, we were able to identify societies who had safety documentation prior to live interviews in order to better structure the interview questions.

Interview: A semi-structured interview comprised of five sections was employed to provide interviewers with open-ended prompts to obtain specific information from the interviewee with flexibility to explore other relevant topics. The interview open-ended questions are included in Appendix 1 Column 2.

Interview Process: The interview was conducted using an open-ended question format. The length was dependent on the responses from the interview subject, and on average, each interview lasted approximately 30 minutes. During the interview, detailed notes on the responses from the subjects were taken, including direct and paraphrased quotes from the subject.

Coding Process: From the interview notes, we selected 10 interviews to review and identify the key ideas from each interview subject's response. We then categorized these key ideas according to themes. These themes became the main code book to analyze the remaining interviews. The code book was reviewed by the faculty advisor and then the coding process was performed by two students in collaboration due to time constraint. We were not able to evaluate the intercoder reliability as the coding process was not performed independently due to time constraint. However, since this is a preliminary study, we believe that a simple coding process using two students was sufficient to provide the necessary information.

Interview sample size: We aimed to interview at least one person from each society with hazardous activity, with a goal of 50 subjects for a representative sample. For qualitative studies, a minimum sample size of 12 subjects is recommended, with the average sample size of 30 subjects [16]. After an initial call for interviews, a snowball sampling method was used to obtain additional interview candidates. We prioritized interviewing members from societies with the greatest number of self-reported hazards based on information collected from the online form. We also note that some societies that operate on OSU campus are not officially recognized by the COE, or were recognized by other OSU colleges, and thus were not included in this study.

Theoretical Framework for Analysis

After the coding of students' interview responses and preliminary evaluation of the identified themes, we decided to use the Bloom's Taxonomy as a framework to analyze the results. Since the participation in co-curricular activities is a part of student learning in an informal setting, analyzing the results from an educational perspective will provide more appropriate insights on improving student safety in an informal learning setting. Most students do not have sufficient industry experience where they are required to go through proper safety training, conduct formal risk assessment on their activities, and potentially face repercussion for failure to report and/or comply. Thus, for our current study, we opted to evaluate student co-curricular activities safety from the learning perspective rather than using industry standards.

Viewing engineering student clubs as an informal learning setting where students learn proper safety procedures and approaches, this study uses Bloom's Taxonomy domains – Cognitive [17], Affective [18], and subsequent Psychomotor [18], to evaluate and analyze student approaches to safety in their co-curricular activities. Since safety practices involve physical application, the psychomotor domain was included in the analysis for this study.

- Cognitive domain focuses on students' knowledge of safety in their student societies' activities, proper protocols and procedures with regards to the use of equipment and materials, and PPE. Student knowledge on accident versus near-miss incidents is considered as part of the cognitive domain.

- Affective domain focuses on students' emotional reactions to accident and near-miss events during the society's activities. In this study, a student's reaction to peer safety behavior, such as speaking up to remind their peers, receiving reminders from peers, and reaction to near-miss events, are categorized under the affective domain.
- Psychomotor domain includes physical movement and skills, and focused on the deployment or execution of safety protocols, procedures, and PPE use, while cognitive domain is focused on the knowledge. In this study, students' proper application of safety protocols, procedures, and use of PPE is categorized as psychomotor learning, for example, the act of discussing or incorporating safety into club discussions.

Results

Online Form for Preliminary Data Collection: We contacted all 46 recognized OSU COE societies to complete the online form. Over a period of approximately four weeks, we received a response from 40 societies. From the online form, nine societies reported dealing with at least one hazard in their regular society activity. Validating the responses through societies' websites, social media, and consultation with EH&S, an additional eight societies were identified who potentially perform hazardous activities in their society's routine activity.

Through the online form and validation, among undergraduate students who participate in co-curricular activities, approximately 27.6% of them deal with potential safety hazards in their routine society's co-curricular activities. Of the 17 societies dealing with hazards, nine societies self-reported hazardous activities. As the respondents to online forms are leaders from societies, this shows that approximately 50% of the societies' leaders are aware that their society's routine activities involve hazards.

Document Analysis: Through online form and validation from professional societies' websites, eight societies were identified to have safety documentation. From the eight societies with safety documentation:

- Two societies shared their documentation with us prior to interviews.
- Six societies mentioned the availability of their safety documentation during the interviews, but it was not shared with us.
- Of the 13 interviewees from three societies with existing safety documentation, five interviewees were not aware of their societies' safety documentation: two held leadership positions in the same society, three were regular members.

Interview: We contacted the 17 societies we identified as involving hazardous activity directly with a call for volunteers, which yielded 27 subjects; we then used a snowball sampling method for subjects, which yielded an additional 15 subjects, for a total of 42 subjects. Of the 42 subjects interviewed, student members of 16 out of the 17 identified societies participated, 10 were regular members and 32 were in leadership positions within their respective society. Of the societies that self-reported hazardous activities, eight of the nine societies participated in the interview. One student society that self-reported hazards did not respond to our requests for interviews.

Coding of interview responses: Using the method described in the methodology section and based on the theoretical framework for analysis, the responses from the interview subjects were coded. Appendix 1 shows the themes identified, the coding, and the count for each coded response. For each coded response, we have identified if the response demonstrates the subject's cognitive, affective, and psychomotor understanding of ensuring their own and their peers' safety during their society's activities. Table 1 shows the frequency where the interview subjects demonstrate cognitive, affective, and psychomotor understanding of safety knowledge, behavior, and practices.

Table 1: Count of responses that demonstrate safety understanding based on learning domain

Responses that Demonstrate Learning Domain	Count
Cognitive	152
Affective	163
Psychomotor	189
Cognitive and Affective	7
Cognitive and Psychomotor	12
Affective and Psychomotor	58
Cognitive, Affective, and Psychomotor	5
Not demonstrating understanding of safety	128
Total	**714**

The results from the coding of the interview responses show students have roughly the same learning in terms of cognitive, affective, and psychomotor regarding safety during their informal societies' activities, with psychomotor learning slightly higher. However, the results also show that students are treating each learning domain independently, for example, based on their responses, students do not necessarily link their knowledge (cognitive) of safety protocol to their actual practice (psychomotor) or to speak up when they see unsafe behavior among their peers. In addition, a considerable number of responses did not demonstrate any understanding of safety procedure and practice among the students.

Among the responses, a few responses were noteworthy as these responses demonstrated the two extremes: lack of safety knowledge and resources available for safety, and proper understanding of safety and reporting needs. The comments were paraphrased below.

- Comments reflecting safety incidents that were not reported to EH&S:
    - Students left a soldering iron on and unattended for an extended period.
    - Students were disassembling a large steel structure which was not properly supported, subsequently causing it to fall.
    - A student sustained injury due to improperly sized PPE while handling liquid nitrogen. Members of the club were unaware of the resources EH&S can provide to assist students with sourcing proper PPE.
    - A student working alone with a butane torch started a contained fire.
- Comments reflecting proper understanding of safety and reporting needs:
    - Students reached out to EH&S for guidance on the transportation process for potentially hazardous fuel chemicals.

- Explosives misfired at a student team competition. The society followed protocol to report the event to competition administration.

In addition to the count, we analyzed the responses to specific questions that gauged students' learning regarding safety from cognitive, affective, and psychomotor perspectives. Table 2 shows the descriptive statistics based on the subjects' responses. As cognition dictates psychomotor activity [13], we found that a lack of student willingness to report near-misses is driven by a gap in knowledge on what type of events should be reported and when to report. We also found how students' perception of safety (affective domain) drives their willingness/unwillingness to report. If students perceive that there may be repercussions for reporting or assess that particular events are not severe enough to report, safety culture is impacted negatively.

Table 2: Descriptive statistics and findings based on coded responses

Domain	Descriptive Statistics	Findings
Cognitive (Knowledge dimension)	24% of subjects would report depending on the severity of the incident.	Subjects lack knowledge on the kind of events that need to be reported.
	26% of subjects mentioned that more knowledge of how to access the near-miss reporting form would increase the likelihood of submitting a report.	Knowledge on where and how to report must be made available and frequent reminders are needed.
Affective (Responding dimension)	21% of subjects perceived that they or their peers had a fear of punitive action as a result of reporting a near-miss.	Fear of retribution, a part of safety culture, must be addressed.
	83% of the subjects did not feel comfortable to speak up when they saw their peers acting in an unsafe manner.	Culture that encourages speaking up is necessary.
	10% of subjects perceived that their club members would have a general unwillingness to report a near-miss.	Culture that encourages reporting is necessary.
Psychomotor (Awareness dimension)	69% of subjects said that safety is not discussed often within their society.	Frequent and consistent safety reminders are necessary.
	57% of subjects report that safety is monitored by club leadership, project leaders, or designated safety leaders.	Promoting and encouraging student ownership of safety is necessary.
Psychomotor (Set dimension)	38% of subjects mentioned an easier process would increase the likelihood of submitting a near-miss report.	Ease of reporting needs to be addressed.

Discussion

From the results, the lack of hazard observation or near-miss event reporting is due to the lack of knowledge on students' part, and a poorly perceived reporting climate. The lack of knowledge is presented in two main aspects: (1) students did not know that reporting safety incidents and near-miss events are necessary to prevent future safety incidents, and (2) students did not know the difference between safety incidents and near-miss events. As for the knowledge of safety in procedures and proper use of PPE, the results from this study show that students have some knowledge in this area, though, students do not always apply their knowledge in practice. In addition, the results also show that students are not aware of the resources available to them through the Department of EH&S in assisting them, designing and reviewing safety protocols, obtaining and fitting proper PPE for their activities, and general assistance in improving their safety while conducting society activities.

From the perspective of general safety culture within student societies, the results show that students either do not understand the need to report or are uncertain of the negative consequence to them or their societies for reporting safety incidents or near-miss events. In addition, the results also show that students did not receive the encouragement or have the confidence to speak up when they observed unsafe behavior from their peers' actions. The lack of knowledge on the overall safety-related reporting, including the initiation of reporting and the outcomes from their reporting, also contributed to students' lack of safety-related reporting. A positive reporting culture is built upon the superiors' demonstration of a just culture [19]. Just culture involves how superiors handle reports, specifically through rewarding, punishing, or doing nothing about the reports. Reporting culture could be fostered by rewarding reporting behaviors regardless of the nature of the reported incident.

To improve student safety during informal learning activities, we need to both educate students on safety procedures and practices, empower students to speak up, and encourage them to apply their safety knowledge into practice. This could be challenging in two aspects: (1) knowledge transfer between formal and informal learning – even though institutions already provide safety training through formal learning activities such as labs and shop classes, questions remain on how do we emphasize to students that they should apply the same safety practice while the instructor/TA are not around; (2) peer pressure and culture change – each student society is a community by itself and will have their own culture and the associated peer pressure; how do we change the culture to encourage speaking up?

Educating students on the industry workplace safety approaches can be beneficial to the students. At a minimum, educating students on the workplace safety hierarchy of control, i.e. Eliminate, Substitute, Engineering Controls, Administration Controls, and PPE [20]. This will inform students that the use of PPE is meant to be the last line of defense in preventing accident.

Applying industry safety management approaches to student societies might be beneficial, however, there are some practical considerations that have to be resolved. Companies that have sound safety management usually have an accountability system where workers are required to report any incident, near-miss event, and potential hazard, and they will be rewarded/penalized for their action/inaction. To create and manage an accountability system for student societies will require considerable resources for tracking, and the reward/penalty system will require extensive consideration from administration.

Conclusion

Despite formal classroom and lab teaching emphasizing safety procedures and protocols, our study found that students' safety knowledge and practices do not seem to transfer to their informal learning setting. In terms of reporting safety incident and near-misses, 24% of the subjects stated that they would report depending on the severity and 21% of the subjects perceived that reporting can result in punitive action. More concerning findings from this study are that 83% of the subjects did not feel comfortable speaking up when they observe an unsafe behavior from their peer, and 69% of the subjects stated that safety was never discussed or mentioned during society activities.

Furthermore, this study shows that despite near-zero safety incidents in formal classrooms and labs, safety incidents and near-miss events occur during student societies' activities and many, if not most, of these incidents and events were not reported to the proper authority. This raises the question of how many of such incidents actually happened, and how do we change the safety culture among the students to increase their safety and improve the data collection. Near-miss reports are leading indicators in improving safety in the industry. How do we translate proven industry safety practices into academia, specifically student societies, while considering the unique characteristics of high member turn-over and frequent change in leadership of student societies?

Student safety in co-curricular activities, specifically in organized student societies, is an important subject as these societies complement student formal learning. Engineering education research has demonstrated that co-curricular activities increase student engagement, and engineering colleges/schools generally encourage students to participate in such co-curricular activities. What can engineering educators do to improve student safety practices in their informal learning activities when figures of authority are not around to remind and enforce safety procedures?

References

[1] A. D. Ménard and J. F. Trant, "A review and critique of academic lab safety," Nature Chemistry, vol. 12, pp. 17-25, 2020.

[2] American Chemical Society Joint Board-Council Committee on Chemical Safety, Safety in Academic Chemistry Laboratories: Best Practices for First- and Second-Year University Students, 8th ed., D. C. Finster, Ed., Washington, DC: American Chemical Society, 2017.

[3] G. Prpich and R. Unnerstall, "Translating Industrial Lab Safety Practices to Academia," Chemical Engineering Progress, pp. 29-34, May 2022.

[4] National Research Council of the National Academies, Safety Science: Promoting a Culture of Safety in Academic Chemical Research, Washington DC: The National Academies Press, 2014.

[5] APLU Council on Research Task Force on Laboratory Safety, A Guide to Implementing a Safety Culture in Our Universities, CoR Paper 1, Washington, DC: Association of Public and Land-grant Universities, 2016.

[6] J. A. Martin, K. A. Miller and E. Pinkhassik, "Starting and Sustaining a Laboratory Safety Team (LST)," ASC Chem. Health Saf., vol. 27, pp. 170-182, 2020.

[7] E. Faulconer, Z. Dixon, J. C. Griffith and H. Frank, "Surveying the Safety Culture of Academic Laboratories," Journal of College Science Teaching, vol. 50, no. 2, pp. 18-26, 2020.

[8] Y. Yang, G. Reniers, G. Chen and F. Goerlandt, "A bibliometric review of laboratory safety in universities," Safety Science, vol. 120, pp. 14-24, 2019.

[9] K. A. McGarry, K. R. Hurley, K. A. Volp, I. M. Hill, B. A. Merritt, K. L. Peterson, P. A. Rudd, N. C. Erickson, L. A. Seiler, P. Gupta, F. S. Bates and W. B. Tolman, "Student Involvement in Improving the Culture of Safety in Academic Laboratories," Journal of Chemical Education, vol. 90, pp. 1414-1417, 2013.
[10] I. O. Staehle, T. S. Chung, A. Stopin, G. S. Vadehra, S. I. Hsieh, J. H. Gibson and M. A. Garcia-Garibay, "An approach to enhance the safety culture of an academic chemistry research laboratory by addressing behavioral factors," Journal of Chemical Education, vol. 93, pp. 217-222, 2016.
[11] I. Schröder, D. Y. Q. Huang, O. Ellis, J. H. Gibson and N. L. Wayne, "Laboratory safety attitudes and practices: A comparison of academic, government, and industry researchers," Journal of Chemical Health & Safety, vol. 23, no. 1, pp. 12-23, 2016.
[12] D.-G. Yu, Y. Du, J. Chen, W. Song and T. Zhou, "A correlation analysis between undergraduate students' safety behavior in the laboratory and their learning efficiencies," Behavioral Science, vol. 13, p. 127, 2023.
[13] T. D. Karapantsios, E. I. Boutskou, E. Touliopoulou and P. Mavros, "Evaluation of chemical laboratory safety based on student comprehension of chemicals labelling," Education for Chemical Engineers, vol. 3, pp. e66-e73, 2008.
[14] J. R. Phimister, U. Oktem, P. R. Kleindorfer and H. Kunreuther, "Near-Miss Incident Management in the Chemical Process Industry," Risk Analysis, vol. 23, no. 3, pp. 445-459, 2003.
[15] E. J. Haas, B. Demich and J. McGuire, "Learning from Workers' Near-Miss Reports to Improve Organizational Management," Min Metall Explor., vol. 37, no. 3, pp. 873-885, 2020.
[16] S. E. Baker and R. Edwards, "How many qualitative interviews is enough? Expert voices and early career reflections on sampling and cases in qualitative research," National Center for Research Methods, 2012.
[17] D. R. Krathwohl, "A Revision of Bloom's Taxonomy: An Overview," Theory Into Practice, vol. 41, no. 4, pp. 212-218, 2002.
[18] Arkansas State University Office of Accreditation & Assessment, "Bloom's Revised Taxonomy: Cognitive, Affective, and Psychomotor," [Online]. Available: https://www.astate.edu/dotAsset/7a3b152c-b73a-45d6-b8a3-7ecf7f786f6a.pdf. [Accessed 26 January 2023].
[19] J. T. Reason, "Achieving a safe culture: Theory and practice," Work & Stress, vol. 12, no. 3, pp. 293-306, 1998.
[20] The National Institute for Occupational Safety and Health (NIOSH), "Hierarchy of Controls," Center for Disease Control and Prevention, 17 January 2023. [Online]. Available: https://www.cdc.gov/niosh/topics/hierarchy/default.html. [Accessed 10 April 2023].
[21] Occupational Safety and Health Administration (OSHA), "Incident Investigation - Overview," [Online]. Available: http://www/osha.gov/incident-investigation. [Accessed 08 October 2021].

Appendix 1: Interview questions and the coded responses.

*Learning domains are C=cognitive; A=affective; P=psychomotor

Interview Section	Interview Open-Ended Questions	Analysis			
		Themes Identified	Learning Domain*	Count n=42	Coded Responses
Section 1: *Establish Project Goal and Rapport*	(1) Please tell us about your role in the organization. How long have you been involved? How did you get involved? What kind of activities do you do?	*Note: Collected the demographic data only.*			
Section 2: *Perception of Safety Culture*	(2) Please tell us more about (activities described in question 1).				
	(3) PPE and documentation specific questions: PPE (Personal protective equipment such as gloves, safety glasses, steel-toed shoes): (a) What PPE does your club use? In which activity does your club use PPE? Is PPE provided by the club or do students bring their own? (b) Documentation: Do students reference the safety documentation each time they are performing an activity? How is the documentation kept - is it online, printed out etc.? Are students required to read the documentation before doing the activities? How useful is the documentation your club has? (c) Signage: How does your club use safety signage? Is it referenced? How often? During what activities?	Awareness of safety documentations	C	11	Yes
			C	30	No
			—	1	N/A
		Note: We did not find any themes in the responses to PPE related questions.			
	(4) How often do people follow (regulations described in Question 3) when performing the activity?	Follow safety protocols	P	12	All the time
			A, P	21	Fairly often/if told to
			P	2	Not often
			—	7	N/A
	(5) How does the club make sure that safety measures are being followed? How frequent/when are students trained to use PPE/follow documented procedures/observe signage, etc.? (Provide a specific example of a range such as weekly, a couple times a term)	Safety discussions	P	13	Often
			A, P	10	As needed basis
			P	15	Not often
			P	1	Never
			—	3	N/A

Interview Section	Interview Open-Ended Questions	Analysis			
		Themes Identified	**Learning Domain***	**Count** n=42	**Coded Responses**
	(6) How frequently is safety discussed within your organization? By student members? By leadership? By faculty advisor? How comfortable do you feel discussing safety with your fellow club members? Leadership? Advisor?	Safety monitoring	A, P	19	Monitored by executive leadership/project leads
			P	14	Self-monitored
			A, P	5	Monitored by designated safety leads
			—	4	N/A
Section 3a: Scenario Analysis #1: *"A student trips over an extension cord that lies across the floor but avoids a fall by grabbing the corner of a desk."*	We would like to provide you with a few scenarios to understand how your club members generally react. Remember that there are no right or wrong answers. The data we are collecting is for research purposes only, so please try to answer as honestly as possible. (7) A student trips over an extension cord that lies across the floor but avoids a fall by grabbing the corner of a desk. (a) How would your club members generally react to this scenario? (b) If you could make a change to this scenario, what would that be?	Reaction to scenario (Responses were coded into categories)	C	18	Only remove the hazard
			C, A	7	Check the person & remove the hazard
			P, C	5	Inform someone & remove the hazard
			C, A, P	5	Check the person, inform someone & remove the hazard
			A	1	Only check the person
			P	1	Only inform someone
			—	5	N/A
Section 3b: Scenario Analysis #2: *"You are working at the mill when you observe a fellow club member working alongside you who has*	(8) You are working at the mill when you observe a fellow club member working alongside you who has forgotten to put on their safety glasses. (a) What is the club safety protocol to handle this scenario?	Reaction to Scenario (Responses were coded into categories)	P	15	Only tell them to put on their safety glasses
			C, P	7	Stop the work then remind them to put on their safety glasses
			P	4	Only report to leadership/faculty
			A, P	3	Tell them to put on their safety glasses and report to leadership/faculty
			P	3	Do nothing
			P	2	Give them safety glasses

Interview Section	Interview Open-Ended Questions	Analysis			
		Themes Identified	Learning Domain*	Count n=42	Coded Responses
forgotten to put on their safety glasses.”			P	2	The club does not have protocol to respond to this situation
			P	1	PPE is provided but not enforced
			P	1	Equipment is distributed by leadership before members start work on equipment
			—	4	N/A
	(b) If you were in this scenario, would you feel comfortable speaking up and asking your fellow club member to put on their safety glasses?	Ease of speaking up	A	37	Yes
			A	1	Maybe
			—	4	N/A
	(c) Based on what you know about your club, do you think most members would feel comfortable speaking up? (If NO) What do you think could be done such that most of your club members feel comfortable enough to speak up?	Perceived ease of speaking up by peers	A	28	Yes
			A	2	No
			—	12	N/A
Section 4a: Near-miss identification **:** *Try to recall an event where an accident <u>almost</u> happened.*	(9) Try to recall an event where an accident <u>almost</u> happened (such as someone almost tripping over an object, almost cutting their finger and needing a bandage, forgetting safety glasses, etc.)	Near-miss knowledge	C	22	Near-miss
			C	4	Safety incident
			C	16	No recollection
	(a) What was your club members’ general response to the event?	Peer’s response to event	P	20	No further preventative action was taken
			C	5	Safety reminder was communicated to club members
			C	3	Changed the protocol for next time
			C	2	Updated safety documentation
			C	1	Improved safety training
			—	11	N/A
	(b) Did your club inform your faculty advisor?		P	4	Yes

Interview Section	Interview Open-Ended Questions	Analysis			
		Themes Identified	**Learning Domain***	**Count** n=42	**Coded Responses**
		Inform proper authority	P	18	No
			—	20	N/A
	(c) Did your club report the event to any other entity or person on campus?	Incident reporting	P	3	Yes
			P	19	No
			—	20	N/A
	(d) How frequently do events of this nature, where an accident almost happens, occur?	Perceived frequency of safety incident	C	8	"Not often"
			C	3	Once or twice a term
			C	3	Once or twice a year
			C	2	"One-off event"
			C	1	"Every once in a while"
			—	25	N/A
Section 4b: *Near-miss reporting behavior*	(10) Events where an accident almost happens are called near-misses and research has shown that reporting and addressing near-misses actually helps to prevent accidents in the future [21]. (a) What is the best way to submit a near-miss report for your club in general? An online form, paper, or something else?	What is the best way to submit a near-miss report for your club?	P	29	Online
			P	8	Report to an individual
			P	2	Paper-based
			—	3	N/A
	(b) How likely do you think your club members are to submit a near-miss report? (IF NO) Why do you think that is the case? Do you perceive your club may be viewed in a certain way as a result of submitting near-miss reports? Why?	Perceived willingness to report	A	10	Dependent on the severity of the near-miss
			A	6	General willingness
			C	6	Dependent if members knew how
			A	6	Dependent on potential repercussions
			A	6	Dependent on ease/simplicity of the process
			A	4	General unwillingness
			—	4	N/A
	(c) How willing are you to submit a near-miss report?	Individual willingness to report	A	16	General willingness
			A	10	Dependent on the severity of the near-miss

Interview Section	Interview Open-Ended Questions	Analysis			
		Themes Identified	Learning Domain*	Count n=42	Coded Responses
			A	7	Dependent on ease/simplicity of the process
			A	3	Dependent on potential repercussions
			C	2	Dependent if interviewee knew how
			—	4	N/A
	(11) What can we do to make it easier for you and your club members to submit near-miss reports?	Approach to increase reporting	A	16	Simplify the process
			C	11	More knowledge on how to report
			A	5	Ensuring anonymity
			C	4	Improved education on near-misses
			A	2	Providing office/lab space for each club
			A	2	Positive incentives for reporting
			A	1	Hold clubs accountable for not reporting
			—	1	N/A
Section 5: *Closing Remarks*	(12) Is there anything else you would like to share with us?	*Note: None provided.*			
	(13) Is there anyone you would recommend (inside or outside of your organization) that we could reach out to get more information?				
	(14) Can we let that person know that you recommended them?				