

Research Safety and Professional Development-A Graduate Course Focused on the Role of Safety in Laboratory Management

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Abstract

A graduate student laboratory-safety course has been developed that encompassed the essentials of safety combined with addressing safety management soft skills. The structure of the course incorporated lectures, guest speakers, student presentations, site visits, in-class discussions and problem-solving. The culmination of the course was a final project report that required the incorporation of topics and skills learned into a safety plan for their future profession. Reviews by the students were very positive and informative but indicated that a flipped-classroom, as well as a two-part course, maybe more impactful.

Introduction

Faculty members often expect that professional skills, communication skills, and safety skills are learned and recognized by graduate students as they work to progress on their degree path. While most graduate programs do not focus on the formal education of these essential secondary skills, some students develop them on their own due to personal attributes and natural talents while some do not. Opportunities are often available which encourage professional development such as managing other students, participation in conferences, leadership positions within organizations, presentations, and writing publications. Commonly, graduate students develop these soft skills by trial and error with little feedback. An area often overlooked is formal safety training as safety is often viewed as an impedance to research or addressed only when correction is needed (Cooper 2016). Typically, only minimum safety training is provided at the university or college level with introductory on-line modules or videos. This approach addresses safety compliance issues more than actual application risks. Taking time for safety education is important for understanding safety applications, risks, and building a culture of safety. Thus, additional safety education should be provided by other mechanisms to build a successful program. An added benefit is that quality safety programs offer the opportunity to develop managerial and communication skills in graduate students by engaging the students through supportive learning (Hill 2013) (Ollis 2016) (Mabrouk 2001).

Incidents in the past 15 years at academic institutions have raised awareness that many graduate students do not have a strong sense of safety and that safety is in a state of crisis (Kemsley 2019). Lack of a positive safety culture in academia is evident by repeated reoccurring issues, Many examples exist. Poor incident/accident reporting and investigations led to the hydrogen-oxygen mixture explosion in 2016 at the University of Hawaii (Benderly 2016). In 2010 at Texas Tech an explosion resulted from inadequate safety communication with students about the scale limit in an SOP (Kemsley 2010). Tragically students have died due to the lack of accountability and enforcement such as Sheri Sanji's death at UCLA in 2008 (Kemsley 2019) and after a student's

complaints were ignored at Beijing University in 2018 (Feng 2018). In response to these incidences, a number of organizations including the American Chemical Society (ACS) and the American Institute of Chemical Engineers (AIChE) have addressed their concerns by creating programs directed at initiating and propagating cultures of safety as well as safety education (National Research Council 2014) (APLU Council on Research Task Force on Laboratory Safety 2016) (Davidson 2018) (ACS nd a) (Center for Chemical Process Safety nd). However, safety education is still mostly reliant on individual faculty members to initiate rather than a formal program for graduate students. In an effort to address continuing issues in safety and enhance professional attributes needed for these graduate student's future careers, a course was created entitled "Research Safety and Compliance for STEM Professionals." The target audience for the safety course was graduate students with at least one year of research experience.

This new course was designed to provide an overview of governmental safety regulation combined with direct application of safety requirements through real-life examples. Due to the smaller class size of five graduate students, a uniquely tailored and interactive approach was taken. The fundamentals of safety were demonstrated in class to apply not only to academic institutions but also governmental, industrial, and business environments. The key to the presentation of course material was a multi-aspect approach combining the history of safety, the emergence of governmental agencies, required regulations, worker's rights, communication approaches, visiting professionals, and field trips. The goal was to create a fast-paced formal environment where graduate students would gain enough knowledge in safety to be able to apply safe laboratory practices, be ready to enter an industrial lab setting, and gain the ability to overcome safety challenges they might face establishing their laboratories. Visiting professionals helped students engage in networking within the safety community as well as identify potential safety-related careers. At the end of this course, the graduate students are empowered to create a safe environment for themselves and their colleagues.

Course Structure

Addressing the entire range of safety-related information needed for a graduate student is challenging by itself especially within the restrictions of a classroom setting. The course content was designed to target a cross-section of areas frequently encountered in collaborative and interdisciplinary science and engineering. Students tend to desire hands-on-training whenever possible but due to the nature and range of students enrolled in the course, a mixture of modalities was used to encourage active student participation. Additionally challenging is preparing these same students for the next phase in their professional careers, one which they most likely will be managing individuals and be responsible for their safety. In order to achieve the goal of training combined with fostering soft skills, a fast-paced format was adopted with intensive lectures similar to professional level safety training, required take-home assignments, class presentations, interactions with safety professionals, and site visits. The class met twice a week for 1.25 hours for a three-credit hour course.

The course objectives were for the graduate students to:

- Learn about general governmental regulation of research activities and application to other fields.
- Receive training for laboratory research that exceeds the University of Arkansas Environmental Health and Safety requirements.

- Achieve professional development: With the knowledge gained in this course, students can work in industry, government, or academic research environments with an understanding of pertinent safety issues and relevant application. Necessary ancillary skills, such as communicating professionally about safety matters will also be developed.

Table 1: Course syllabus

Class	Topic Description	Assignments and In-class discussions
1	Introduction: What is safety?	Assigned to watch the CSB video " <i>Experimenting with Danger</i> "
2	The history of governmental regulation: agencies and applicability	In-class discussion of the CSB video, Lab safety module
3	University, state, and federal (OSHA and EPA) requirements, structure, committee approvals	Slide presentations on university incidents
4	The psychology of safety part 1 / Manager and principal investigator responsibilities/	In-class discussion of leadership
5, 6	The psychology of safety- part 2 / safety communication strategies	In-class examples and discussions on motivating employees and conflict resolution
7, 8	Chemical safety: NFPA, GHS, SDSs, inventory control, storage (guest visitor)	Peroxide formers and sensitizers modules, In-class use of SDSs
9, 10	Biological safety: classification, work strategies, equipment, (guest speaker and visit labs)	Biosafety training modules
11, 12	PPE/ respiratory protection/engineering controls	Hands-on interaction with PPE
13, 14	Compressed gas cylinder safety / heated and pressurized systems (site visit)	Gas safety training module hands-on instruction in the lab
15, 16	Waste Regulations/Environmental Requirements and Laws	Slide presentations on incidents involving waste, Waste module, Watch video on spill clean-up procedures
17	EH&S site visit (guest speaker)	Discussion with professionals
18	Emergency Protocols and Management: Part 1: lab basics and emergency equipment	Slide presentations on a hazardous waste incident
19	Emergency Protocols and Management: Part 2: How to identify & professional help	Fire safety module, Watch spill response and cleanup video
20	Compliance/Import-Export Controls (guest speaker)	
21	Principals of research and laboratory design/Importance of ventilation	In-class design of bio and chemical labs
22	Tour of lab construction areas and building infrastructure, speak with lab designers	
23	Audits: Preparation and Inspections	Presentation of EH&S examples
24	Risk Analysis /Standard Operating Procedures	Risk assessment homework
25	Reporting Incidences, Accidents, and Near-Misses	In-class discussions
26	Electrical /Radiation/ Laser safety	Laser and radiation module
27	Ergonomics in the lab and office/Repetitive Injuries	In-class physical exercises
28	Controlled Substances/Compliance (visitor)	
29	Hazardous Goods Transportation: shipping, receiving, and moving chemicals between labs	
30	Emerging research areas and unknown hazards: nanomaterials, waste remediation, etc.	
	Final project due	

Activities and Lectures

Lectures were given on each topic area with copies of presentations given to students to form a reference booklet. Examples of applications were integrated into the lectures based on personal and professional experience along with pertinent case studies such as the 2008 UCLA incident and the 1984 Bhopal disaster. These lectures were fast-paced, similar to safety professional certification courses. All in-class activities were designed to provide learning opportunities for each of the course objectives. The latter portions of each class focused on a recap of the materials presented and resources available at our university, in industry, and from governmental agencies. Emphasis was given to short and simple communication formats which are the backbone of all safety communications. Exposure to a demanding schedule consistent with professional settings helped communicate expectations for the course.

Due to the uneven exposure of students to safety as a subject area, the first lecture was key to forming the basis for the course by redefining the term safety. Safety is a broad topic encompassing any aspect where the protection of individuals, entities, equipment, or the environment is proactively managed to minimize damage. Students typically viewed safety as consisting of a set of rules to follow or the addition of personal protective equipment (PPE). This common misunderstanding missed the purpose and application of safety concepts as being an integral part of quality research as well as safety's contribution to a positive working culture. Good research and safety done correctly have always been partners, not mutually exclusive, and serve to create a quality program.

Because students in the course were from multiple areas of disciplinary focus ranging from science education to engineering, engaging the students in areas outside of their degree focus was necessary. To promote cross-fertilization of knowledge, at least 30 minutes of each class was reserved for class discussions or student presentations. Presentations were restricted to the topic area being discussed. A one-slide and three-minute presentation format was utilized to practice organizational skills as well as concise visual and verbal communication. Students had the freedom to choose the examples presented. Typically, the example chosen was from personal experience or the discipline focus of their degree. This freedom of choice worked well as the students were interested in the material and could share concerns with the group. In-class discussions centered around "best practices" and learnings from these "unsafe" situations. Students commonly asked questions which encouraged the sharing of discipline-related knowledge.

Modules and quizzes created by the University of Arkansas Environmental Health and Safety (EH&S) for employee safety training as well as modules created for the Department of Chemical Engineering were given as homework assignments. These modules supplemented and reinforced the information presented in the course. Typically, these modules took no more than 30 minutes to complete.

An example of a homework assignment that was very thought-provoking for the students was the situational risk assessment problems. Each student was given a research situation that required utilizing a five-step process based on ACS recommendations, rubrics, and identifying the highest risk hazards (American Chemical Society nd b):

1. Identify hazards
2. Analyze risks by assigning a value (probability versus severity)
3. Select controls to mitigate the hazard risks
4. Reanalyze the risk
5. Make an informed decision

Students were asked to keep in mind the effects on workers, neighbors, and the buildings where the work would take place. The problem sets given were deceptively simple such as:

“There is a need for really pure acids for your research analysis with no trace metals, side products, or moisture. The research requires the use of refluxing/condensation of the highly corrosive acids.”

“A project involves working on the link between pigs and infectious diseases on a farm. The research requires analysis of pig waste samples in order to assess the health of each pig farm.”

Course grades

It is essential that the students understand the importance of this course and integrate the safety knowledge gained into their work. As a result, scoring in the course also reflected these broad goals. Grades given in the course were based on technical understanding, ability to communicate, ability to contribute to the understanding of the objective, and ability to meet deadlines. The course and final project requirements were communicated at the beginning of the semester and repeatedly emphasized throughout the semester. The grade breakdown was as follows:

In-Class Activities	20%
Projects & Assignments	30%
Quizzes	10%
Final Project	40%

Key to continued student engagement was the requirements of the final project. The final project was to create a safety plan for a future profession incorporating at least seven of the weekly topics covered in this course. The default profession was a tenure track research professor researching your dissertation topic unless another profession was approved. Two students chose alternative professions of an educational safety consultant and the president of a start-up company based on a research generated product. The project report length was set at a one-page minimum written for each topic page. Use of graphics, illustrations, tables, and charts was encouraged. Topic choices were required to be approved and be shown to be relevant to the chosen profession and research area. Time management was the responsibility of the students with only reminders given in class to help set goals for project progress. Completed reports were an average of 16 pages. To create a successful project report the student needed to identify potential safety issues and address the planned application of safety concepts. Again, clear and concise communication was valued over complex verbiage. Grading was based on organization, identification of target issues within the planned scope of research, professionalism, readability, and clear recommendations that could be utilized by others.

Table II: Final Project

Introduction	Describe the future profession you envision yourself going into, what type of research you will be doing, and the general role safety will play
Topic 1-Roles & Responsibilities	Outline the roles of personnel, the delegation of authority and designated safety responsibilities
Topic 2-Communication Strategy	Outline preferred elements in the psychology of safety you will use to create a safety culture, identify your preferred communication standards, identify at least one conflict resolution method and proactive technique
Topic 3-7:	Student choice but needs to be approved. Identify key safety concerns for your lab and methods of addressing those concerns
Conclusion	Describe how your plan will enhance your future success
References	

Communication and Safety Management Skills

An area where the students appeared to have the least previous knowledge was in common communication methodologies and available communication modalities. Initially, the plan for the topic “the psychology of safety” was to address components of a safety culture, both holistic and systems approaches. However, it became readily apparent by questions from students that more was needed. A change of focus was quickly made to introduce the students to concepts taken from basic active listening techniques, OSHA’s “Better Safety Conversations”, applications of the “COIN” and “Ask, Tell, Ask” conversations models, and practicing difficult conversations by role-playing (OSHA nd). A number of situations encountered frequently by managers and early-career faculty were posed. The students were allowed to discuss these situations and engage in conflict resolution approaches.

As previously described, integrated throughout the course was an emphasis on simple yet significant communication strategies. Examples were given of both effective and dysfunctional communication as well as corrective actions. Key to this instruction was the student’s understanding of how and which method to apply in a given situation. The advantages and disadvantages for verbal, written, and digital communication were discussed. Each of these forms play an important and specific role in safety as well as management of personnel.

Interaction with Campus Departments

One of the goals for the course was to allow students to meet and see a range of professionals. Interactions of visitors from the University of Arkansas’s EH&S Department and the Office of Research Compliance were invaluable. All of our visitors and guest lecturers had former careers outside of academia. Students were able to hear examples about the role of safety in government and industry as well as at our university. Additionally, students realized many people were present to support them in their career. Interaction with our guests opened their eyes to formerly unknown resources for safety and other areas.

Difficulty

An unforeseen barrier to participation in the course was that the course was listed through the chemical engineering department (CHEG) in the spring semester. Because of the CHEG listing, many departments on campus did not recognize the course for credit within their degree program. Additional feedback from other departments indicated the spring semester was already

overloaded with required special topics in their degree programs however there was much interest in a fall semester program.

The small class size allowed for individualized creation of problem sets which would not be possible with a larger class. If this course expands and grows in size, class discussion will be made more difficult. One of the approaches which could be applied to overcome large class sizes and engage students would be to create a flipped classroom such as done by Hill *et al.*, 2019 for their “Introduction to Safety” for graduate students. However, since this class was not designed to be an introductory course, if students do not put effort into the readings before class, then a flipped classroom would severely hinder problem-solving and application discussions. A motivation strategy would need to be created.

Student Response/Assessment

Course evaluations were derived from two sources: an end-of-course online survey and class discussion on ways to improve the course for future students. Student evaluations indicated that the content of the course was of considerable interest and helpful to students. In the informal class discussion, the students unanimously suggested that the course content be “flipped,” with required readings being given prior to class. In this manner, presentations could be studied beforehand so that class time could be devoted to discussions, problem-solving, guest lecturers, and site visits.

In the class discussions about improving the course, students requested a two-semester format be considered for the future. The students suggested the two-part format due to the realization that some of them had been operating unsafely in laboratories, yet they still wanted exposure to other skills necessary for developing a professional plan. An “Introduction to Safety” was proposed for beginning graduate students and “Safety for Future STEM Professions” for third or fourth-year graduate students. Students recommended the second course provide a more in-depth approach on the psychology of safety components due to the realization that some of the difficulties they were encountering as students were due to lack of established communication patterns combined with the lack of clearly defined roles and responsibilities. Overall the reviews by the students were very positive and informative.

Representative Comments were:

“I thoroughly enjoyed the real-world application we received. I learned how to make my own lab better, learned policy, and learned about real-life safety accidents and incidents.”

“I really enjoyed the interdisciplinary graduate level of learning achieved in this class.”

“I believe the final project is very useful and applicable to my future plans”

“More in-class exercises would be a great way to do more critical thinking about the concepts we cover. More case studies would also be nice.”

One area that is of interest, which was not addressed, would be measuring student improvement in the course. For example, a survey at the beginning and end of class for graduate students as well as their advisors could add a new level of insight. Advisors provide a unique perspective on student execution of safety versus student self-assessment.

Final Thoughts

In summary, we have developed a twice a week full semester course “Research Safety and Compliance for STEM Professionals” that encompassed the essentials of safety combined with addressing safety research management skills. After participation, students were empowered to create a culture of safety and have the confidence to recognize, challenge, and be proactive about potentially unsafe situations. This course will continue to evolve and should be taught as a flipped class in the future. If other departments are interested in participating, a two-part course may be possible. Currently, the chemical engineering department at the University of Arkansas already provides a fundamental safety instruction as part of the orientation of new graduate students under my direction. The inclusion of an expanded safety leadership component would be greatly beneficial to students which could be done in the second course.

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