RESEARCH ARTICLE

# Analysis of injury data to improve safety and training

We used injury data to evaluate trends in laboratory-related injuries at Iowa State University from 2001–2014. We determined that students (graduate assistants and student employees) are the most frequently injured group, comprising 40.9% of the laboratory-related injuries, suggesting the need to expand and enhance safety training. To this end, we are moving away from classroom-only training and are incorporating multiple learning methods into our training program. In addition, we are utilizing near misses, narratives, and anecdotes to enhance learning. Given that lacerations was one of the most prevalent injury types, we determined the underlying factors that were contributing to this injury type. We ascertained that the three leading causes of lacerations were equipment, glassware, and blades, and determined that the vast majority (74.4%) of glass-related injuries were the result of glassware breaking during lab work. We are sharing this data with our campus researchers and are encouraging them to take the appropriate steps to limit these types of injuries, such as the use of appropriate containers and inspection of glassware before use to ensure that it is not cracked or broken. Changing the prevailing mindset of safety compliance and moving to a mindset of safety culture is perhaps one of the essential factors in increasing laboratory safety in academic laboratories. Thus the Iowa State University Environmental Health and Safety department is moving from a compliance-centered culture to one in which we use data to drive the decision-making process and our communications with researchers.

**By H.E. Simmons, B. Matos, S.A. Simpson**

## INTRODUCTION

The American Chemical Society (ACS) formed a task force in 2011 to investigate incidents such as the 2010 explosion at Texas Tech University that seriously injured a graduate student and the 2008 fatality of a researcher at the University of California Los Angeles (UCLA). The resulting report (*Creating Safety Cultures in Academic Institutions: A Report of the Safety Culture Task Force of the ACS Committee on Chemical Safety*)[1] defines safety culture as "a reflection of the actions, attitudes, and behaviors of its members concerning safety" and focuses on enhancing safety culture as the driving force for change in academic research labs.[1] In fact, the report goes so far as to state that "a strong safety culture is required to protect employees… (and)… students".[1] However a literature survey undertaken by McGarry et al.[2] highlights that the predominant response to the need for a strong safety culture has been to improve regulatory compliance as well as to distribute protocols and procedures. Unfortunately, there has been far less emphasis on how to enhance the safety culture within an academic environment.

There are a number of hurdles to establishing a strong safety culture within a university setting. The first is the relatively decentralized power structure typically seen within academic institutions. The very nature of basic research does not lend itself to a centralized power structure, but rather fosters the autonomous nature of independent research with minimal administrative oversight. The second is that the academic research setting lends itself to a wide variety of potential safety hazards, including biological hazards, chemical hazards, radiological hazards, as well as toxic hazards.[3] This lack of a centralized power base in combination with the extensive range of potential hazards means that the top-down management style typical of Environmental Health and Safety (EH&S) in industrial settings is often untenable in academic research. Culture is defined as the shared events and perceptions among the members of an organization.[4] In a research environment, if we as an EH&S department want to share a culture with the researchers on campus, we need to understand their perceptions. Therefore, we are beginning to move away from a strictly regulatory-based approach and are using data to drive our decision-making processes and as the basis for our communications with campus researchers. As a part of this process, incident data from 2001 through 2014 from the Iowa State University (ISU) University Human Resources (UHR) first report of injury (FROI) database was used to evaluate trends in the types and frequencies of

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laboratory-related injuries that occur on campus.

The Occupational Safety and Health Administration (OSHA) Recordkeeping regulation (29 CFR 1904) is important for "evaluating the safety of a workplace...and implementing worker protections to reduce and eliminate hazards.[5]" However, despite this assessment, research into incident rates in academic laboratories is relatively sparse, with examples including Cal/OSHA and Chemical Safety Board investigations into UCLA and Texas Tech.[6] Incident investigation has a long history of use as a mechanism to prevent future injuries, with the central idea that, in identifying the cause of the incident, the underlying mechanisms could be identified and corrected to ensure that similar incidents do not occur in the future. However, recent research suggests that biases are inherent in this strategy, and a recent review indicates that investigators are biased toward assuming an unsafe act on the part of the employee as the causal factor.[7] Therefore, we sought to remove a component of this bias and used FROI data to determine who was sustaining injuries on the ISU campus over a fourteen-year period (2001–2014), and what these injuries were. The use of this data set allowed us to determine the areas of laboratory safety on which we should focus our resources, without assigning blame to specific individuals.

Iowa State University (ISU), located in Ames Iowa, is an Association of American Universities accredited, land-grant institution with the oldest public veterinary college in the United States. ISU has been experiencing record enrollments for the past seven years, currently with ~30,000 undergraduate students and ~5,000 graduate students in addition to 6,000 faculty and staff. ISU comprises eight colleges that offer 108 bachelor's degree programs, 112 master's degree programs, 81 Ph.D. programs, and one professional program. The ISU EH&S department is a comprehensive service-orientated department consisting of 35 safety professionals who provide a full spectrum of research support services.

## METHODS

Incident data from 2001 through 2014 was sequestered from the University Human Resources (UHR) FROI database, which is currently used by UHR to evaluate accidents and is also used by EH&S to conduct accident investigations. This data was stripped of university ID numbers and names prior to analysis to ensure that anonymity was maintained. Data from all years was used to assess general trends, such as percentage of FROI that were laboratory-related injuries, as well as the determination of injuries by job title and injury classification.

During the process it became apparent that the FROI incidents were not reported consistently; for instance, some animal-induced injuries resulting from contact with research animals were classified as bruises, so in an effort to classify the injuries in a more consistent manner, the incidents' descriptions were used to reclassify the injury types. FROI reporting has changed drastically through the years, and injuries reported prior to 2007 have exceedingly brief injury descriptions. Some examples of animal-induced injury descriptions from FROI reports submitted pre-2007 include "Hurt Chest/ribs," "Hurt right knee," and "Cuts to head." Clearly it is not possible to determine what type of animal or injury was involved based on these descriptions. Thus the reanalysis of injury classification was only performed on the 2007 through 2014 data. Given that we were interested in the causal factors underlying the incidents, we altered the categories slightly and added the following categories: "chemical," "biological," "eye injury (not chemical)," and "noise." "burns" was changed to "heat" to differentiate from chemical burns, which were included under "chemical," and we combined all repetitive strains (wrist, shoulder, and elbow) into one category, "repetitive strains." Several other categories were shortened; for example, "animal bites & injuries" was shortened to "animal injuries." "bumps, bruises, contusions etc." was shortened to "contusion."

For the analysis of lab-related incidents by job title, all groups that constituted less than 5% of the total were combined and classified as "other," for a total of 28.7% (see Table 1 for a list of titles included under "Other"). Similar job titles were combined; for instance, "Research Associate" and "Research Assistant" were combined into "Res Assoc" (see Table 1 for a complete list of combined titles). All categories discussed in this study, including students, are university employees.

**Table 1. For the Analysis of Lab-related Incidents by Job Title, All Groups that Constituted Less Than 5% of the Total Were Combined and Classified as "Other." In Addition, Similar Job Titles Were Combined. The First Column Lists the Titles Used in the Analysis, and the Second Column Lists the Titles Used in the Original FROI Data.**

| Title Used in Analysis | Titles in FROI |
|---|---|
| Prof | Professor<br>Associate Professor<br>Assistant Professor<br>Instructor |
| Res Assoc | Research Associate<br>Research Assistant |
| Lab Tech | Lab Assistant<br>Research Technician<br>Lab Technician |
| Other | Ag Specialist<br>Clinician<br>Field Lab Tech<br>Histo Tech<br>Hourly Worker<br>Intern<br>Laborer<br>Radiographer<br>Postdoc<br>Seasonal<br>Seed Analyst<br>Visiting Scientist |

The data were analyzed using Microsoft Excel and Statistical Package for the Social Sciences (SPSS) (Version 19.0).[8]

## RESULTS

### 2001–2014

The number of lab-related incidents at ISU from 2001–2014 was 1,497 out of 8,071 total reported FROI.

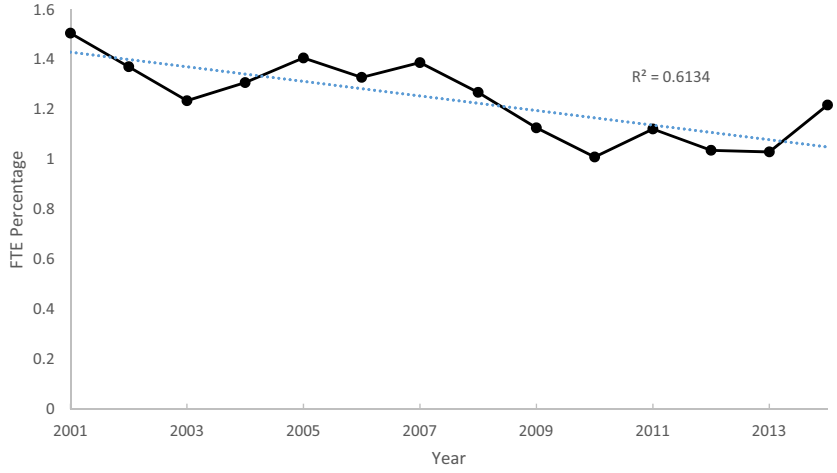


**Figure 1. The percentage of reported lab-related incidences per full-time equivalent employee from 2001–2014.**

The average percentage of incidents at ISU that were lab-related from 2001–2014 was 18.4% (range 15.2–21.7%). Given that the university has experienced growth (both student enrollment and in number of employees) over this time period, we were interested in assessing how the percentage of FROI lab-related incidents fluctuated as a function of full-time equivalent employees (FTE). Therefore, we calculated the percentage of lab-related incidences per FTE from 2001–2014 and determined they averaged 1.24% (range 1.01–1.51%). The overall trend in the number of lab-related incidents appears to be decreasing over time ($R^2 = 0.6134$) (see Figure 1).

Lab-related incidents by job title revealed that the group injured most frequently from 2001–2014 was Student Employees (18.5%), followed by Animal Caretakers (14.7%) and Graduate Assistants (13.9%) (see Figure 2). All groups that constituted less than 5% of the total were combined and classified as "other," for a total of 28.7% (see Table 1 for a list of titles included under "Other"). Given that as a group students (Graduate Assistants and Student Employees) appear to be among the most frequently injured, we calculated the percentage of students who were involved in lab-related injuries per year from 2001–2014. We ascertained that this group comprises on average 33.3% (12.3–47.6%) of all the lab-related incidents over this 14-year period. Most concerning is this percentage appears to be increasing over time ($R^2 = 0.7409$) (See Figure 3).

An analysis of injury classifications from 2001–2014 revealed that lacerations and punctures were the most prevalent injury type and constituted 25% of the total injuries, with the second largest group being bumps, bruises, and contusions at 13.4%, and the third largest group being animal bites and injuries at 13.2% (see Figure 4). However, as outlined in the methods section, injury classification did not always match well with the injury descriptions provided in the FROI; therefore, we redefined injury classifications by utilizing the injury descriptions. Given that the FROI reports prior to 2007 contained very little information in the injury descriptions, these years were eliminated from the data for the reanalysis of the injury descriptions.

### 2007–2014

An analysis of the percentage of lab-related injuries by job title at ISU from 2007–2014 revealed a similar pattern to that seen in the 2001–2014 data with Student Employees being the group with the highest number of incidents at 25.5%, followed by Graduate Assistants at 15.4%, and Animal Caretakers at 12.8%. A determination of the injury classification for these years was also similar to that seen for the 2001–2014 data, with the predominant class being lacerations and punctures at 20.3%, animal bites and injuries at 16.1%, and bumps, bruises and contusions at 12.0%. Interestingly, however, the reanalysis of the injury classification revealed a shift in the injury categories, such that animal-induced

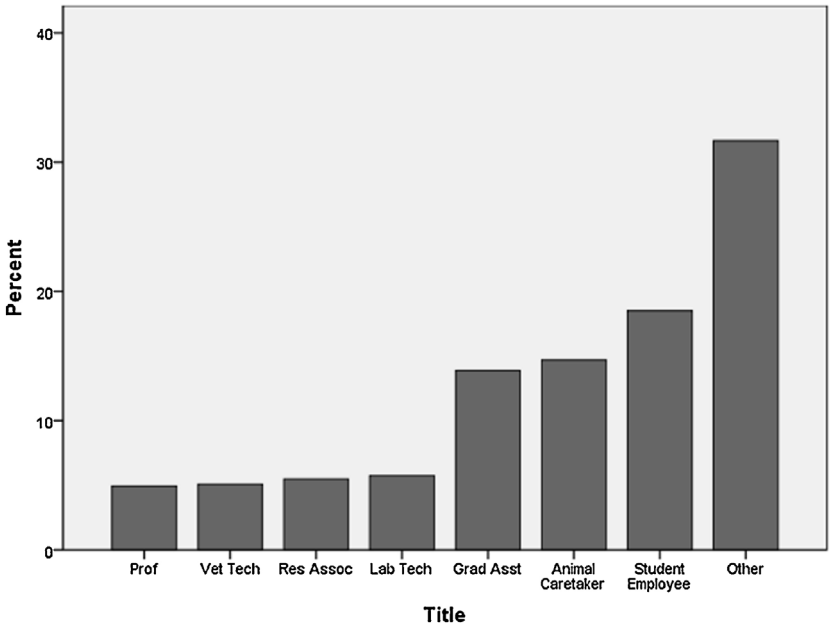


**Figure 2. The percentage of reported lab-related injuries at ISU from 2001–2014 by job title. All titles at less than five percent were combined and are labeled as "Other."**

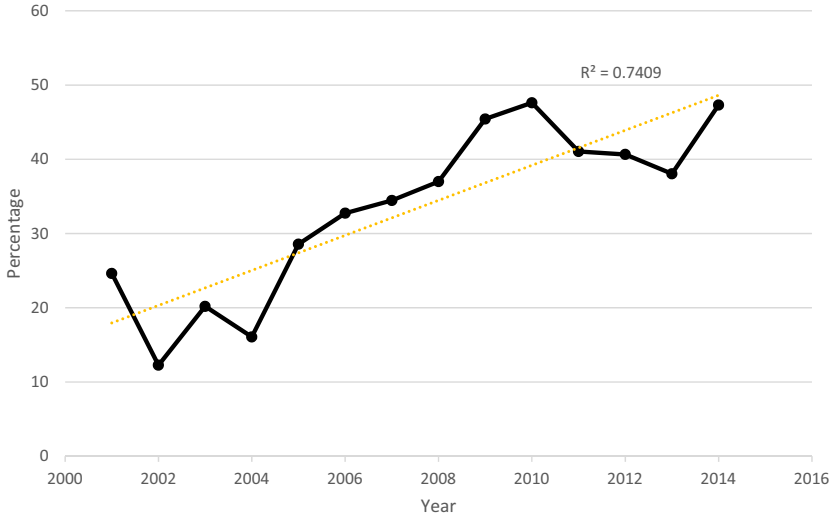


**Figure 3. The percentage of reported lab-related incidents for Student Employees and Graduate Students (combined) at ISU from 2001–2014.**

injuries became the predominant injury, occurring at 26.1%; the lacerations class was second most frequent at 23.3%, and the third largest injury group was chemical-related injuries at 9.2% (see Figure 5). The bumps, bruises, and contusions category dropped to 8.4%. This shift is mostly likely due to the way in which people entered their information into the FROI form. For instance, of the 208 animal-induced injuries recorded from 2007–2014, only 109 of these were actually entered as animal bites and injuries with the remainder being entered as other types of injuries; for instance, 34 were entered as bruises, 18 as sprains and strains, and seven were entered as back strain etc.

Given the high number of animal-induced injuries that occurred between 2007 and 2014, we analyzed what types of animals were causing these injuries and determined that

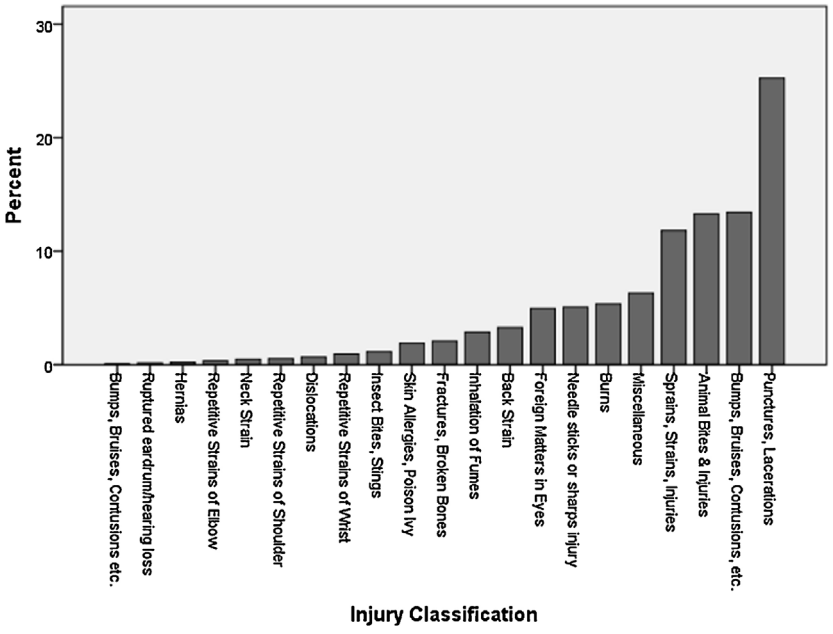


**Figure 4. The percentage of reported lab-related incidents at ISU from 2001–2014 by injury classification as recorded in FROI.**

the largest portion of animal-induced injuries were from bovines (23.0%), followed by felines (20.1%), and then domestic canines (14.8%) (see Figure 6). We also determined which injury types were occurring most frequently and found that bites comprised the majority of animal injuries (43.3%), followed by kicks (11.1%), with striking injuries being third (9.1%), followed closely by crush injuries (8.7%) (data not shown). Examples of strike injuries include the animal using its head or body to strike or push. Feline bites constituted the largest number of bite injuries (40%), followed by domestic canines (27.8%) and then equines (6.7%). As might be expected, kick injuries were predominantly the result of injuries received from bovines (56.5%) and equines (39.1%), as were crush injuries, with bovines constituting 72.2% of the injuries and equines 27.8%. In contrast, strike injuries were more evenly distributed between bovines (26.3%), equines (21.1%), porcines (21.1%) and domestic canines (15.8%).

As lacerations were the second largest type of lab-related injuries, we assessed the types of implements causing the injuries, and determined that 27.4% were caused by equipment. This category includes a wide range of items, such as ice machines, grinders, freezers, cages etc. Lacerations caused by equipment were closely followed by those resulting from blades (25.3%) and glass (23.1%) (see Figure 7). The blade category includes implements such as razors, scalpels and scissors. Further analysis of the type of activities undertaken when the lacerations occurred revealed that the majority of the glass-related injuries (74.4%) were the result of glassware breaking while working in the lab, with half of these injuries occurring to graduate students.

Given that students (graduate assistants and student employees) were the most likely group to be involved in a lab-related incident from 2007–2014, we analyzed the types of injuries that these groups reported. We ascertained that the most common injury type for graduate assistants was lacerations (30.1%) followed by chemical-related injuries (24.4%), with needlesticks being the third most common injury

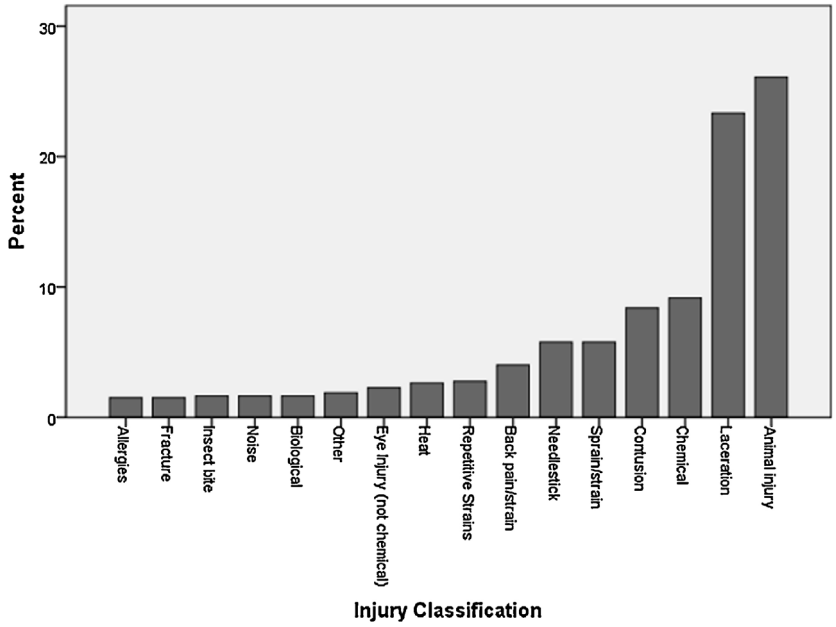


**Figure 5. Percentage of reported lab-related incidents at ISU from 2007–2014 by injury classification after re-analysis. (During the process it became rapidly apparent that the FROI incidents were not reported consistently; for instance, some animal-related injuries were classified as lacerations; in an effort to classify the injuries in a more consistent manner, the incidents' descriptions were used to reclassify the injury types).**

(10.6%). Interestingly, when the same analysis was applied to the student employee population, we determined that there were significant differences: namely, the most common type of injury received by the student employees was animal-induced injuries (29.6%) followed by lacerations (29.1%), and then contusions (8.4%). Although chemical-related injuries were the most commonly occurring injury in the graduate assistant group, this injury type only accounted for 7.9% of the student employee injuries and needlesticks only 3.9%. Likewise, although animal-induced injuries was the most common injury type recorded for the student employees, this injury type only accounted for 4.9% of the injuries received by the graduate assistants.

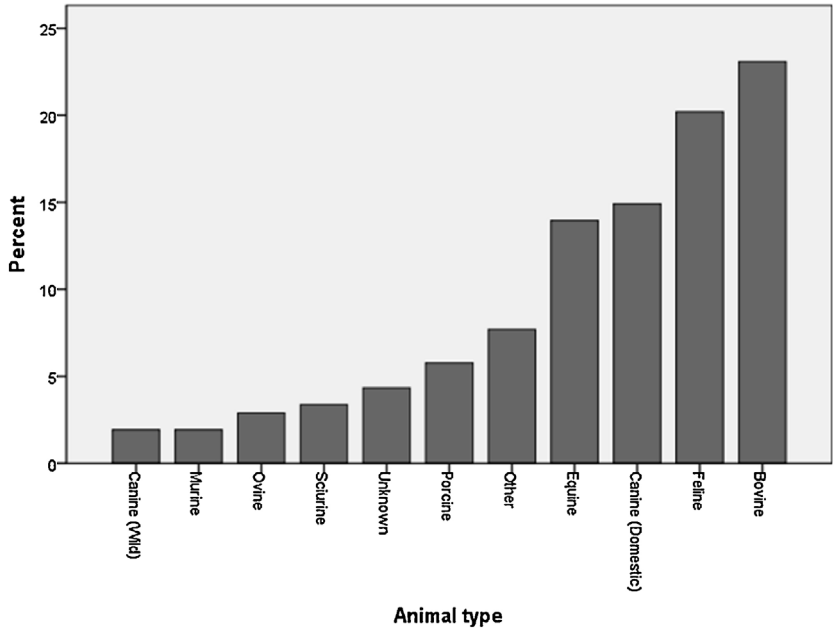


**Figure 6. The percentage of reported animal-induced injuries categorized by animal type that occurred at ISU from 2007–2014.**

## DISCUSSION

One of the most striking results of this analysis was the number of student employees (both graduate and undergraduate) that are involved in lab-related incidents. Even more concerning is that the trend appears to be increasing over the 14-year period (2001–2014), with the two highest years being 2010 and 2014 at 47.6% and 47.3%, respectively (see Figure 3). While it is certainly true that this increase over time is partially due to the manner in which student employees are classified (for instance, from 2001–2005 the title "hourly worker" was used as a classification, obscuring the absolute number of student employees in this time frame), it remains a troubling trend. In addition, as the opportunities for undergraduate research are increasing in United States universities[9] a concurrent increase in the number of undergraduate students employed in academic research labs could also be expected. Arguably one of the best approaches to addressing this issue is to enhance safety training for students. In a recent study undertaken by Altabbakh et al.,[10] they determined that fewer than 30% of the engineering and science undergraduates at Missouri University of Science and Technology who completed their survey had any formal safety training. In addition only 47% of these were able to successfully identify the safety requirements necessary for laboratory or shop assignments.[10] Although not focused exclusively on students (which constituted 26.1% of the respondents), the 2012 survey of the safety of academic laboratories in the United States, commissioned by the University of California's Center for Laboratory Safety, reported similar findings. In

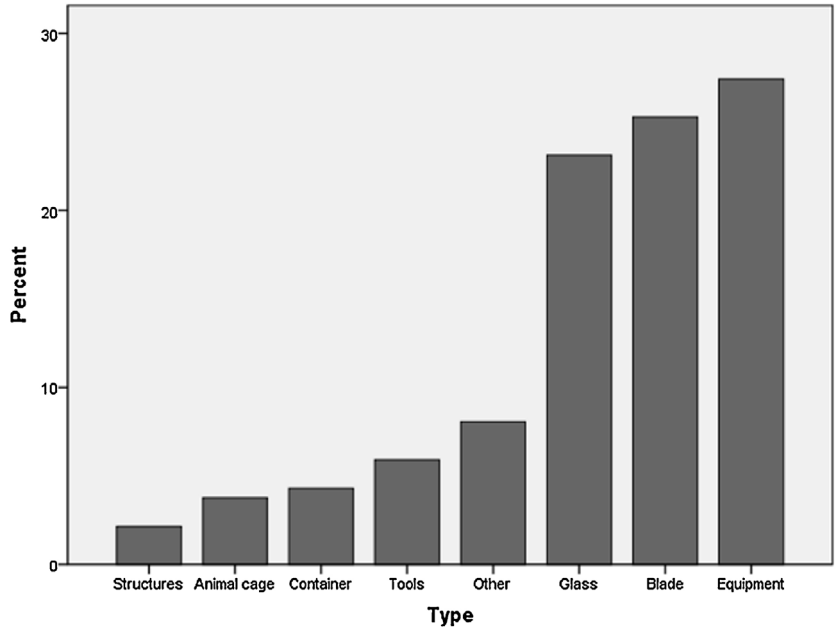


**Figure 7. The percentage of reported laceration injuries occurring in lab-related incidents at ISU from 2007–2014 by the implement that caused the injury.**

this survey only 59% of the respondents strongly agreed or agreed with the statement that "I received safety training on the specific agent/hazards I work with".[11] In addition, lack of training was cited as one of the causes of the accident involving the graduate student at UCLA who died from burns received after a pyrophoric chemical that she was working with (t-butyl lithium) was exposed to air and ignited.[12] These findings suggest that enhanced safety training is needed in academic laboratories. This assertion is further supported by the fact that appropriate training has been cited as mitigating the effects of laboratory accidents. For instance, at The Ohio State University, an explosion and fire occurred that completely destroyed the lab, with estimated damages ranging from $200,000 to $300,000. Despite the fact that this was a three-alarm fire, no-one was seriously injured and a subsequent review of the incident revealed that training helped prevent serious injuries from occurring.[13]

Given that 40.9% of the laboratory-related incidents at ISU from 2007–2014 involved student employees, focusing on enhancing our student safety training is a critical component of our safety program. At ISU we have responded to the need for enhanced training and have increased our focus during lab surveys on documentation of safety training for student employees. We are incorporating multiple learning methods into our training program and are moving away from strictly classroom-based training to more interactive learning. For instance, we have expanded our Laboratory Safety Orientation for incoming graduate students to include additional "hands-on" activities such as conducting a hazard assessment, using a fire extinguisher to put out a simulated fire and completing a mock laboratory safety survey. In addition, we are in the process of expanding our outreach to a number of organizations that are involved in student training in the laboratory, such as departmental safety representatives and postdoctoral associates.

Another potential strategy to enhance safety training could be to incorporate safety modules into foundation laboratory classes, and at ISU, we have followed this model in a few of our departments: for instance, our chemistry department has a half-semester safety course that is required coursework for all incoming graduate students. Additionally, safety lessons can be integrated into existing models, and Butler University has successfully investigated this strategy and incorporated a hands-on module into their organic chemistry laboratory section that emphasizes the importance of hygiene in the lab as well as the importance of personal protective equipment (PPE). They used a fluorescent indicator dye to visualize contamination both on the students' hands as well as on laboratory surfaces, and PPE use increased to 100% as a direct result.[14]

As lacerations were one of the most common injuries in laboratories at ISU from 2001–2014, we are focusing on broken glassware and sharps during laboratory safety surveys. We are sharing the injury data with our researchers and are encouraging them to use appropriate containers for blades and scalpels. We are also encouraging lab workers to inspect their glassware before use to ensure that it is not cracked or broken. Even though our percentage of glass-related injuries is lower than other reported rates, 23.1% versus the 54% reported by a review of chemistry labs in 13 academic institutions in Colorado,[15] we are also considering instituting a program where the university aids in subsidizing the replacement of cracked and/or broken laboratory glassware (such as flasks and beakers). Dealing with animal-induced injuries is not straightforward, as animals are, by their very nature, unpredictable. We are, however, investigating the current training and techniques for handling animals in order to ascertain where improvements could be implemented.

Clearly, assumptions are inherent in using FROI data, one of which is that all lab-related incidents are reported, which is certainly not the case. In fact, the 2012 survey of safety of academic laboratories in the United States revealed that 23% of the respondents indicated that they had seen a colleague sustain an injury that was not reported, and 25.9% reported sustaining an injury themselves that they did not report.[11] This highlights the need to alter the negative perceptions that surround the reporting of laboratory incidents as well as near misses. A near miss, as defined by OSHA and the

National Safety Council Alliance, "is an unplanned event that did not result in injury, illness or damage – but had the potential to do so".[16] As many serious incidents are preceded by near misses, instituting a program that records and investigates these near misses can mitigate or even prevent more serious incidents from occurring, thereby improving safety.[16] Companies instituting these programs have reported successes; for instance, PIKA International Inc. reported an incident rate drop from 3.62 to 0.817 and a drop in OSHA reportable incidents from 4 to 1 in one year.[17] The implementation of a near-miss reporting system in the pediatric anesthesia department at The Children's Hospital in Denver, Colorado, reported a dramatic increase in the number of incidents that were reported (from 4 to 150 over a three-month period), allowing the implementation of system changes and thereby enhancing patient safety.[18] A near-miss reporting system was one of the U.S. Chemical Safety Board's recommendations to Texas Tech after the 2010 incident, and other academic universities are also starting to implement these types of systems, including, Pennsylvania State University Materials and Research Institute (http://www.mri.psu.edu/facilities/safety/near-miss-reports.asp), Boston University (http://www.bu.edu/orc/near-miss-reporting/), Drexel University (http://drexel.edu/dornsife/research/research-centers/FIRST/past-projects/Near-Miss-Reporting/), University of Wisconsin (https://www.wisconsin.edu/ehs/osh/near-miss/) and University of Nebraska-Lincoln (https://scsapps.unl.edu/EHSNearMissReporter/).

In addition to increased focus on near misses, another strategy to enhance learning is the use of narratives or anecdotes. In psychology, personalizing narratives are thought to improve learning,[19,20] and it is believed that safety messages are more effectively conveyed when using narratives with emotive appeal than when using narratives that rely on statistics alone.[21] This strategy has been used successfully in the safety profession (for examples: 22,23), and anecdotes or narratives about laboratory incidents that occur within a department and/or university could be an effective way to personalize safety issues. Academic institutions are beginning to use anecdotes and narratives as a way to increase awareness about safety issues. For instance, Princeton University has an anecdotes page (https://ehs.princeton.edu/laboratory-research/anecdotes) that explains actual incidents that have occurred on their campus. At ISU we are introducing anecdotes and narratives in departmental safety meetings and seminars to improve safety-related learning.

It could be argued that the single most important factor in increasing safety in academic laboratories is changing the prevailing culture and moving from a mindset of safety compliance to one of safety culture. In the 2012 survey of safety of academic laboratories in the United States, 41.6% of the respondents agreed that "Safety training in my organization is focused on training compliance requirements rather than on improving laboratory safety." This highlights the fact that university environmental health and safety departments are typically viewed as enforcement agencies rather than as service departments. At ISU we are striving to change this perception of the department and of safety in general. One of the ways in which we hope to move from an atmosphere of compliance to enhancing a safety culture is to use data to drive the decision-making process within our department. In addition to the study described herein, in 2013 our laboratory safety group undertook a benchmarking survey in order to assess and enhance our laboratory safety program.[24] As a department we intend to continue this process of moving from a compliance-centered culture to one that is supported by data.

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