Division of Chemical Education, Inc.

AMERICAN CHEMICAL SOCIETY

Increasing the Society's Role in Promoting Chemical and Laboratory Safety

Response prepared by CHED Safety Committee and
Endorsed by the Division of Chemical Education Executive Committee
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Prologue

The Division of Chemical Education (CHED) recognizes the importance and central role of safety knowledge, skills, attitudes, and values in enabling its members to achieve their personal and professional goals, as well as to advance the strategic goals of the American Chemical Society. As described in the vision and mission of its Safety Committee, CHED seeks to embed accurate safety instruction at all educational levels, and to provide resources and strategies to help educators and chemists function safely when using chemicals. [1]

For undergraduates, safety is often introduced at the general chemistry level using a set of rules that encompasses the laboratory code of conduct describing appropriate dress and behavior, the use of personal protective equipment, the location and function of essential safety equipment, best practices for handling chemicals including use and disposal, etc. Effective safety instruction, however, requires much more than this. To be successful throughout their careers, chemists (and other scientists who take chemistry courses as part of their education) must learn to be proactive in the management of hazards and risks, how to develop and integrate a culture of safety in all their activities, and where to find the information to do these things.

The process of identifying hazards, evaluating risk, developing procedures, and reviewing best practices to mitigate risk must be taught throughout the curriculum and students' academic careers. A positive safety culture in academic institutions requires the participation and commitment of all educators and researchers to safe procedures, training, and education. All faculty must be held accountable for maintaining clean, well-organized, and safe research laboratories, as well as for the continuing safety education of their research students.

Leading indicators of a true culture of laboratory safety include regular safety discussions at every faculty or group meeting, documented review and analysis of all "misses" and "near misses" in the chemistry lab, routine and non-routine safety audits and inspections, and consideration of these best practices in hiring, tenure, and promotion decisions.

The answers below are from the perspective of chemical educators (more so than "chemists" at large). We first address the two overarching or leading questions which were posed (perhaps not rhetorically) in the June C&EN commentary, The ACS's Role in Safety, *and then move on to answer the bulleted/numbered questions at the end of the commentary.*

[1] http://www.divched.org/committee/safety

Despite these and other guidelines that have been issued, incidents continue to happen. What are we missing?

Except for events that could be categorized as "acts of god," such as a weather catastrophe that affects the lab or manufacturing operations, chemical safety specialists argue that *all such incidents* are preventable whether these are mishaps during a chemical demonstration or an explosion at a chemical plant. Where root cause analysis leads to the conclusion that human error was a contributing factor, someone either 1) knowingly acted in an unnecessarily risky fashion or 2) was unaware of some hazard or risk. In either case, this represents *a weak or absent safety component of, or fundamental flaw in, their chemical safety education*. Chemistry departments have an educational and moral responsibility to prepare students to move into their careers or next phase of their education with appropriate safety knowledge and training to keep themselves, their peers, and their communities safe.

In the culture of academic institutions, it is often difficult to incorporate chemical safety into the business model for faculty behavior. Requiring safe behavior in the research laboratory is sometimes seen as encroachment on academic freedom and maintaining a safe, organized, and clean laboratory as a distraction from "getting the real work" done. We disagree strongly with the perpetuation of this culture and maintain that academic research labs must not only meet OSHA regulations with regard to safe chemical practices but go beyond regulatory compliance to foster an environment where safety is an equal component with all other aspects of quality research. This is the laboratory environment of many large and small chemical companies. This means including good hazard and risk analysis in experimental design. This has been nicely articulated in the Committee on Chemical Safety (CCS) publication, *Creating Safety Cultures in Academic Institutions.*[2]

Do we have a commitment to procedures, training, and education? Do we have strong safety cultures?

Our collective commitment is not absent, but neither is it strong. As articulated by the ACS Committee on Professional Training (CPT) in their *Guidelines for Bachelor's Degree Programs*, the call for a thorough safety education in BA/BS programs is clear but the CPT has limited investigative and enforcement powers. Also, while CPT guidelines are applied to ACS-approved programs, they can only be viewed as "best practices" for chemistry programs that are not approved. Thus, while there is some intention to foster strong safety cultures, the fact that it was necessary for the CCS to produce a document called *Creating Safety Cultures in Academic Institutions* suggests that the Society has work to do in this regard.

The circumstances in graduate programs are hardly much better, although improving on some campuses. The 2012 ACS Presidential Commission report, *Advancing Graduate Education in the Chemical Sciences*, speaks to the issue of safety in academic research laboratories with the synopsis, "Academic chemical laboratories must adopt best safety practices" and further urges

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[2] *Creating Safety Cultures in Academic Institutions*, ACS CCS, https://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/academic-safety-culture-report-final-v2.pdf

that, "Safety as a *culture* must be consistently led by example in all graduate programs in the chemical sciences." [3] Again this suggests that strong safety cultures are lacking.

We expect that a paradigm shift in principal investigator (PI) behavior will only occur when a culture of safety is explicitly included as part of the educational curriculum. Future researchers will model their behavior on their experiences in research labs starting at the undergraduate level. As chemical educators, we can teach the rules, principles, best protocols, and prudent practices in the teaching labs; but if those practices are not reinforced by mentors in their research labs, best practices will fail and poor safety culture will be continued.

PIs who are given the responsibility of directing research at an academic institution should be held accountable for the condition of their lab space and the chemical safety education of their research students when it comes time for tenure and promotion.

What more can the ACS do to promote safety? Here we answer the "seven questions."

1. **Should ACS Publications and CAS increase safety content and considerations in our publications and online information?**

   Yes! All publications should summarize the results of hazard and risk analysis for experimental procedures, as described in the new *Guidelines for Chemical Laboratory Safety* published by CCS. We believe the best approach is to require a clear statement of hazards and risks that includes direct explanations of how procedures and safety precautions have been designed to eliminate or mitigate risks.

   In a recent, seminal analysis of required safety statements in a wide range of chemistry journals (both ACS and non-ACS) the authors concluded that the descriptions of hazards and risks and the inclusion of steps to minimize risk are dramatically lacking.[4] The ACS can take a leadership position by requiring all ACS journals to review their policies on safety statements for authors and reviewers.

   Raising the standards for writers, reviewers, and editors of ACS journals will have an added benefit of raising awareness of safety among a broader population of chemists than those who consider themselves safety professionals. In this fashion, all publications can do a better job of teaching the knowledge and skills inherent in safe chemistry laboratory work.

2. **How can we ensure that all ACS content (print, virtual, video) not only conforms to safety best practices, but actively promotes best practices?**

   The CCS is largely responsible for producing content that "conforms to safety best practices" and does the job well. The CHED Safety Committee has recently updated the

[3] *Advancing Graduate Education in the Chemical Sciences*, ACS Presidential Commission on Graduate Education in the Chemical Sciences, 2012, p. 38.

[4] Grabowski, L., Goode, S. Review and analysis of safety policies of chemical journals. *Journal of Chemical Health & Safety*. **2016** *23* (3), http://dx.doi.org/10.1016/j.jchas.2015.10.001.

Safety Guidelines for Chemical Demonstrations.[5] Similarly, we note, with gratitude, that the CPT "upgraded" the safety guidelines for bachelor degree programs quite significantly in the 2015 edition of its *Guidelines*. Collaboration between CPT and the CCS was important in this process.

Divisions should review their publications and resources on a regular basis to ensure that information about safety hazards and risk is up to date and reflects current best practices. This may be accomplished by recommending that divisions appoint standing safety committees, as CHED has done. Alternatively, divisions may seek liaisons from CCS and/or the Division of Chemical Health and Safety (CHAS) to review new published content for their adherence to safety standards. Current and future publications should incorporate safety analysis into their review process, as discussed in Question #1. Reviewers and editors should document the analysis.

To offer one example of a resource that would benefit from such a review process, we suggest that ACS create an updated version of *Starting with Safety.* This chemical safety video program was produced in the early 1990s and is now quite dated. ACS-approved programs want to use ACS resources! The fact that this popular training video is still being used by many institutions across the country 25 years after its copyright date is testament to the need for ACS to serve as the authoritative source for chemical laboratory safety information. Indeed, safety videos are a popular and effective way to communicate best practices. The CCS has produced many fine documents and reports, but these have been generated almost entirely by volunteer efforts of its members. The American Association of Chemistry Teachers (AACT) has made it clear that good videos are much more desired (than printed materials) at the pre-college level.

Moreover, the ACS can help promote best practices by continuing to foster the inclusion of safety in the workings of the AACT and also by reaching out, as appropriate, to the National Science Teachers Association (NSTA) and other entities to better reach high school chemistry teachers. If the ACS could become involved in the development of a certification program for high-school science teachers, this would be desirable by those groups.

3. How might ACS increase its programming related to safety at our national and regional meetings?

Recommending that divisions appoint standing safety committees would assist with this objective. In collaboration with their respective programming committees, divisional safety committees can solicit, recommend, and co-sponsor symposia and other presentations related to safety at local, regional, and national meetings. Increasing the amount of safety content included in technical division programming would especially benefit graduate students, postdoctoral associates, and early-career professors who are often the most well-represented groups attending technical sessions. Seeing and hearing

[5] Safety Guidelines for Chemical Demonstrations (2016), CHED. http://www.divched.org/content/safety-guidelines-chemical-demonstrations-0

how hazard and risk analysis is effectively integrated into all aspects of their chemical research will help inculcate the benefit of this best practice as a core value of the ACS.

Also, as described above in Question #2, technical divisions may actively seek liaisons from CCS or CHAS to attend their executive committee meetings. Liaisons can update divisions about newly released safety resources or regulations and discuss their impact.

4. **After the Bhopal, India, tragedy, the American Institute of Chemical Engineers launched its Center for Chemical Process Safety; it is now the "go-to," authoritative source on the subject. Is there an analogous role for ACS in chemical laboratory safety?**

Absolutely, YES! This would be an ambitious undertaking, but there is currently no single authoritative source of comprehensive chemical safety information for chemists.[6] The proliferation of online resources represents at once a great opportunity but also significant challenges for individuals seeking accurate and reliable chemical safety information. ACS can perform a valuable service for its members, the greater broader chemistry enterprise, and society at large by reviewing, collating, and curating an online bibliography and/or set of reference materials related to chemical safety. Indeed, the *ACS Strategic Plan for 2016 and Beyond* already lists this objective as its Number 1 Goal — to be the most authoritative, comprehensive, and indispensable provider of chemistry-related information and knowledge-based solutions. Chemical safety must surely be included in this objective!

We also note that the CCS, in collaboration with others, produced a widely-heralded booklet, *Identifying and Evaluating Hazards in Research Laboratories*, as a direct response to the Chemical Safety Board recommendation for such a publication, and this publication has recently been formatted online to function as an interactive resource.[7]

5. **Through our Committee on Professional Training, ACS approves bachelor's degree chemistry programs. Part of this approval involves an examination of safety policies and procedures. All ACS-approved chemistry departments must have a written chemical hygiene plan consistent with Occupational Safety & Health Administration and state standards. Are there ways to measure various institutions' underlying safety cultures as well?**

As discussed in the introductory paragraphs of this commentary, all academic institutions should be encouraged to focus on leading indicators of a culture of chemical safety in their departmental meetings, programs, and activities. Chemistry departments should be

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[6] Prudent Practices is now perhaps the best single volume of chemical safety information but this single book falls short of the chemical analog of Center for Chemical Process Safety. Many research universities have developed very extensive websites with regard to safety that could serves as models for and ACS venture in this direction.

[7] Identifying and Evaluating Hazards in Research Laboratories, ACS CCS, https://www.acs.org/content/acs/en/about/governance/committees/chemicalsafety/hazard-assessment.html

required to document and provide evidence of the efficacy of these activities as part of the ACS process for approving bachelor's degree chemistry programs. *Creating Safety Cultures in Academic Institutions* has a specific list of 17 recommendations that can serve as a useful checklist for chemistry programs.

Ethics, information literacy, and chemical safety are intertwined and must be regarded as more than simple skills or other applications of knowledge (as they are now characterized in the CPT Guidelines). Chemists must be taught how to locate primary, peer-reviewed chemical safety information, just as they would find any other peer-reviewed information for research. Chemists cannot truly be considered ethical if they are not following best safety practices with their science to protect their students and the environment. The CPT should work on strategies to integrate these three areas of knowledge into a standard four-year curriculum.

Indeed, the current ACS exam in *Chemical Health and Safety* was produced in 1995 and due to low sales has not been reviewed or revised in the past 21 years. This may be viewed as a proxy measurement of the low priority that the chemical education community places on safety instruction. The CHED Safety Committee is now working closely with the Director of the Exams Institute to produce a revised *Chemical Health and Safety* exam that will better meet market demands in light of the new CPT recommendations about safety instruction.

The CPT can also work to promote degree tracks or concentrations in chemical safety. More chemists completing their undergraduate work with a deeper understanding of chemical safety will shift the paradigm. These students will go on to run academic and industrial research labs, and they will model better behavior.

The question posed also includes: "Are there ways to measure various institutions' underlying safety cultures as well?" This can be a vexing process as we consider both leading and lagging indicators of safety culture. At the least, as a first, indirect measurement of a safety culture, we can examine the chemistry program at a college or university to locate safety instruction and evaluation in the curriculum. Evaluating the effectiveness of such education is somewhat more complicated, but surely possible. At both the undergraduate and graduate levels, we can also examine the safety record, (a lagging indicator,) of an institution.

6. **Can ACS partner with other organizations to promote tools that will help institutions strengthen their safety programs? The Society of Chemical Manufacturers & Affiliates (SOCMA) provides its ChemStewards technology to industrial laboratories. Does it have applicability in academic labs?**

Beginning with the first edition of *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards* in 1995[8] and continuing to the present with the 2016 release of *Chemical Laboratory Safety and Security: A Guide to Developing Standard Operating Procedures*,[9] The National Academies of Sciences (NAS) has a long and well-established history of promoting chemical safety. ACS members and official representatives have served on NAS committees for the publication of these and other important chemical safety resources. The ACS should explore the creation of formal partnerships with NAS and other government or private entities to ensure that accurate, reliable, and practical information concerning chemical safety will continue to be readily available to all academic and labs and chemical practitioners.

With regard to chemical education, as noted above, ACS can foster better connections between its divisions and committees and both AACT and NSTA in order to provide better contact with high school chemistry teachers who, as a cohort, have very modest presence in the ACS.

We also observe that the education of chemical engineers includes more coherent safety instruction features. The ACS should examine these programs to determine what we can best import into the education of chemists.

7. Should ACS include safety explicitly within its core values?

Yes! Safety and ethics are so closely tied to the overall value of the chemistry enterprise that they must be part of the Society's core values. The vision of the ACS, to improve people's lives through the transforming power of chemistry, depends on an underlying, implicit assumption that chemists will always work safely to optimize the benefits and minimize the risks associated with the use of chemicals or the applications of chemical processes. Chemical safety is the foundation of the ACS vision and its mission, and it should be explicitly acknowledged as such. To the degree that the values articulated by the ACS provide guidance to chemical educators, we would welcome the specific inclusion of safety as a core ACS value.

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[8] *Prudent Practices in the Laboratory: Handling and Disposal of Chemicals* (1995, 2011). National Research Council, National Academies Press. https://www.nap.edu/catalog/12654/prudent-practices-in-the-laboratory-handling-and-management-of-chemical

[9] *Chemical Laboratory Safety and Security: A Guide to Developing Standard Operating Procedures (2016).* National Research Council, National Academies Press. https://www.nap.edu/search/?term=Chemical+Laboratory+Safety+and+Security