Collaborative efforts between faculty and embedded safety professionals to improve critical thinking skills of undergraduates

254th ACS National Meeting, Washington, DC
Driving Factors for Safety Education in the 21st Century

- Interdisciplinary work – A changing research environment
- Discovery-based research projects (CURE)
- Novel materials with unknown hazards
- Younger, less resilient, and less skilled student workers
- Information overload
- Internationalization
The Changing Research Environment

Late 19th & Early 20th

Mid 20th

Late 20th & Early 21st
Moving Lab Safety Into the 21\textsuperscript{st} Century

Identify Hazards from previous events

Hierarchy of Controls

- Elimination: Physically remove the hazard
- Substitution: Replace the hazard
- Engineering Controls: Isolate people from the hazard
- Administrative Controls: Change the way people work
- PPE: Protect the worker with Personal Protective Equipment

20\textsuperscript{th} Century
Training & Controls selected based on Rules + Chemical Intuition

21\textsuperscript{st} Century
Safety systems based on education, improved culture, and documented Risk Assessment

Change through Safety Education
Training vs. Education
Safety Training

- Rule & skill based
- Training is based on “one & done”
- Focuses on compliance with regulatory obligations – check the boxes
- Service often provided by personnel from EHS which can create an “us vs. them” or environment in academia (the safety police)
- Often standardized and not necessarily tailored to consider the research occurring
Safety Education

- Risk & understanding based
- Does not replace training
- Focuses on creating chemists with the knowledge, skills, and attitude needed to work independently in an academic lab
- Incorporated into the curriculum by faculty
- Can be customized to consider the research occurring or the preferences of the PI
- Teaches risk assessment, critical thinking, ethical behavior, and information literacy
The Embedded Safety Professional (Ouch!)

- Familiar with how academic research happens and understands how researchers work and think
- Often has a faculty appointment, is housed in the department, and involved with day to day activities occurring
- Reports to the chair or dean
- Can be a liaison to EHS and represent faculty
- Focused on education and promotion of safe research
Additional Benefits

• You build trust with the faculty and students!

• New ideas and knowledge are created and disseminated to the research community
The Spiral Education Approach
The Spiral Approach

• In education a spiral approach to learning methodically builds on what has been previously learned
• It is often used in disciplines which are information intense, conceptually complicated, or have high complexity
The Spiral Approach – Chemical Safety

• Starting in high school, we want to create cognitive categories in students or KSAs (knowledge, skills, and attitudes) in a process called accommodation

• Once a KSA exists, it can be will be modified and expanded as students acquire more safety education in a process known as assimilation

• Future chemical researchers need KSAs for
  – Recognizing & understanding hazards
  – Assessing & managing risk
  – Preparing for the unexpected
The Spiral Approach

• This approach to safety requires a shift in thinking – Safety is more than a “skill”

• Incorporates technical knowledge and cultural change creating categories

• Assimilates chemical safety as KSAs become part of the chemistry curriculum
The Spiral Approach

• Spiral chemical safety encompasses both technical and cultural aspects
  – Technical tools provide information and increase knowledge
  – Cultural tools increase leadership and empowerment
A Spiral Learning Approach To Safety Education
<table>
<thead>
<tr>
<th>Educational Stage</th>
<th>Knowledge</th>
<th>Skills</th>
<th>Cultural Aspects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Chemist</td>
<td>Identify and estimate significance of emerging risks</td>
<td>Make risk decisions and teach risk assessment</td>
<td>Accountable for group performance</td>
</tr>
<tr>
<td>Graduate Researcher</td>
<td>Develop procedures with reducing risks in mind</td>
<td>Use Risk Assessment tools to propose risk levels for review</td>
<td>Oversee others’ safety practices</td>
</tr>
<tr>
<td>Mentored Researcher (UG, CURE, REU, etc.)</td>
<td>Review procedures; locate information to identify hazards</td>
<td>Learn to use Risk Assessment tools</td>
<td>Raise questions and concerns related to risk</td>
</tr>
<tr>
<td>High School Student</td>
<td>Learn RAMP Principles; understand rules</td>
<td>Select Applicable Rules</td>
<td>Respect Rules</td>
</tr>
</tbody>
</table>
Methodology & Tools

**Knowledge**
- Acquisition of information
  - For example: GHS Tools: CPT Safety Education Guidelines

**Skills**
- Using information in specific context
  - For Example: Math and Lab Operations Tools: SACL and Prudent Practices

**Attitude**
- Advancing Best Practices
  - For example: Group learning Community safety awareness
  - Provides: Leadership and Empowerment

- Classes ACS and other publications
- Demonstrations Classes Webinars
- Story Telling and Videos
Safety Education Across the Curriculum
K-12 Teachers – In Service Professional Development

- Webinar for ACS American Association of Chemistry Teachers (2014)
- Webinar for NC-ACS Local Section Innovative Project Grant (IPG) (2017)
- Workshop supported by A&S Dean and Math Science Education Center (2017)
K-12 Teachers – Pre-Service Methods Class

Recent demonstration methanol fires:

1. New York City, NY – January 2014
2. Reno, NV – September 2014
3. Denver, CO – September 2014
4. Raymond, IL – October, 2014
5. Chicago, IL – November, 2014
6. Tallahassee, FL – May 2015

CSB video "After the Rainbow", 11th Grade, Hudson, Ohio, January, 2006
Safety Course Developed

**Chemical Safety**
Spring 2017

Is your chosen field of study in one of the sciences? How about technology or art? Maybe you plan on a career in medicine or medical research? If so, this course will benefit you by teaching you how to locate information to safely work with new and hazardous chemicals.

Maybe you want to teach in NC? Did you know that Science Safety is now part of the NC Standard Course of Study in our schools?

Just a few of the topics of relevance:

- Developing a “Culture of Safety”
- The Laboratory Standard or Hazcom, which applies to me?
- Chemical Hazards/hazard analysis
- Reading a Safety Data Sheet
- Choosing appropriate Personal Protective Equipment
- Hazardous Waste Procedures
- Understanding Hazard & Risk Analysis

CHE 2526 is scheduled on Tuesdays from 11:00 – 11:50 for 1 hour credit.
Risk Assessment

- **2014** – Our department added a graded hazard identification and risk assessment assignment to our Capstone course – we used the “Job Hazard Analysis” (JHA)
- **2016** – Based on program assessment results, the assignment was moved to “Introduction to Research” course (CHE 3000)
- **2016** The pedagogy used with the assessment results were published in the ACS Symposium Book Series – *Integrating Library and Information Literacy into Chemistry Curricula*[^2]

Student Engagement in Safety

Recognized Opportunity
<table>
<thead>
<tr>
<th>Complex</th>
<th>CAS</th>
<th>Formula</th>
<th>8 hour TWA or Ceiling</th>
</tr>
</thead>
<tbody>
<tr>
<td>cobalt(II) carbonate</td>
<td>57454-67-8</td>
<td>CoCO$_3$ $\cdot$ xH$_2$O</td>
<td>0.02 mg/m$^3$</td>
</tr>
<tr>
<td>palladium(II) chloride</td>
<td>7647-10-1</td>
<td>PdCl$_2$</td>
<td>No Data</td>
</tr>
<tr>
<td>aluminum sulfate octadecahydrate</td>
<td>7784-31-8</td>
<td>Al$_2$(SO$_4$)$_3$ $\cdot$ 18H$_2$O</td>
<td>2 mg/m$^3$</td>
</tr>
<tr>
<td>chromium(III) chloride</td>
<td>10025-73-7</td>
<td>CrCl$_3$</td>
<td>0.5 mg/m$^3$</td>
</tr>
<tr>
<td>copper(II) sulfate pentahydrate</td>
<td>7758-99-8</td>
<td>CuSO$_4$ $\cdot$ 5H$_2$O</td>
<td>1 mg/m$^3$</td>
</tr>
<tr>
<td>nickel(II) nitrate hexahydrate</td>
<td>13478-00-7</td>
<td>Ni(NO$_3$)$_3$ $\cdot$ 6H$_2$O</td>
<td>0.015 mg/m$^3$ 0.10 mg/m$^3$</td>
</tr>
<tr>
<td>iron(III) chloride hexahydrate</td>
<td>10025-77-1</td>
<td>FeCl$_3$ $\cdot$ 6H$_2$O</td>
<td>1.0 mg/m$^3$</td>
</tr>
<tr>
<td>vanadium(IV) oxide sulfate hydrate</td>
<td>123334-20-3</td>
<td>VOSO$_4$ $\cdot$ xH$_2$O</td>
<td>0.050 mg/m$^3$ *</td>
</tr>
<tr>
<td>mercury(II) oxide</td>
<td>21908-53-2</td>
<td>HgO</td>
<td>0.025 mg/m$^3$</td>
</tr>
<tr>
<td>yttrium(III) nitrate hexahydrate</td>
<td>13494-98-9</td>
<td>Y(NO$_3$)$_3$ $\cdot$ 6H$_2$O</td>
<td>1.0 mg/m$^3$</td>
</tr>
<tr>
<td>potassium permanganate</td>
<td>7722-64-7</td>
<td>KMnO$_4$</td>
<td>0.2 mg/m$^3$</td>
</tr>
</tbody>
</table>
# Acetyl Acetone

<table>
<thead>
<tr>
<th>GHS</th>
<th>Information</th>
</tr>
</thead>
</table>
| Warning | BP 138 deg C  
FP 34 deg C (Closed cup)  
Flashback along vapor trail may occur  
Above 34 deg C explosive vapor/air mixtures may be formed |
| Danger  | LD50 (oral, rat) = 570/760 mg/kg bw (f/m)  
LC50 (inhalation, rat) = 5.1 mg/l/4 h (1224 ppm)  
LD50 (dermal, rabbit) = 790/1,370 mg/kg bw (f/m) |
| Warning | Vapor irritating to eyes. Liquid irritating to skin and eyes.  
May cause damage to organs through prolonged or repeated exposure (central nervous system, thymus) |
|       | Incompatible with oxidizing materials  
Odor Threshold 0.010 ppm |
“Hey, these guys learned how to do a risk assessment in CHE 3000, let’s have them prepare a JHA for their independent project!”
Novel Implementations in Research Labs
Storyboarding – Idea From Faculty

• First developed at the Walt Disney Studio during the early 1930s

• Storyboards are visual organizers used for previsualizing a video sequence

• One advantage of using storyboards is that it allows the designer to experiment with changes in the sequence before production begins

http://instructionaldesign.org/storyboarding.html
Storyboarding – Idea From Faculty

Biodiesel Synthesis Steps

Planning
1.0
2.1
3.2
4.3
5.4
6.5
7.6

Setup

Experimental

Reaction information

Emergency Planning

REACTION PROCESS
Prevent Exposure

Recognize Hazards
- Chemical (health)
- Chemical (physical)
- Sharps (syringe)
- Chemical spills

Barriers
- Set up in certified fume hood
- Synthetic scale only
- PPE
- Equipment training (#??)
- Spill tray

Chemical Waste
- Label completed prior to work start with names of chemicals

Controls for Failed Barriers
- Eyewash/Shower – Ensure function and clear path
- Emergency phone numbers and procedure known
- Fire extinguishers and exits clear

Experimental

1. Combine in 50 mL round bottom flask (RBF)
“We have some chemicals that have a high hazard, specifically acute toxicity and pyrophoric properties. I train students to handle them under inert atmosphere. What do you think I could additionally do to train students?”

<table>
<thead>
<tr>
<th>Student must be trained on use of chemicals and process prior to work (check all that apply)</th>
<th>PI Initials</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student demonstrates proper use of Schlenk line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student demonstrates proper cannula transfer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student can describe the hazards of pyrophoric chemicals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proper PPE for pyrophoric chemicals is understood and in use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency procedures for an incident with pyrophoric chemicals can be explained</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“I like your checklist idea. I will incorporate that in the lab journal.”
A portion of the course grade was for attending the training and a portion was for completing a risk assessment.

From Syllabus:

*Safety training and assignment will count as 5% of the overall numerical grade/evaluation of student performance*
Obstacles
Upside

• Faculty are consulting with me on how they can improve safety in their research labs
• Faculty are more engaged with safety in teaching labs and the curriculum in general
• Faculty are learning risk assessment
• Students are leaving our program with a better foundational understanding of chemical safety and feeling empowered!
Upside

One of our labs has been doing some big no-no's with waste. I started training in the sickle cell lab and noticed they were using stain and dumping it down the sink. That didn't seem right so I read the kit inserts and learned that it is carcinogenic, should NOT be thrown down the sink but into a waste container, and should be used in a hood. I told my supervisor and we made the changes which will now be added to the SOP. I was excited and wanted to share. I even taught my supervisor that the reagent bottles should not be held by the pouring handle. I still remember everything you taught me!
Questions???