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

254th ACS National Meeting, Washington, DC

ACS Chemistry for Life®
AMERICAN CHEMICAL SOCIETY

CH&S CONNECTING CHEMISTRY AND SAFETY

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August 21st, 2017

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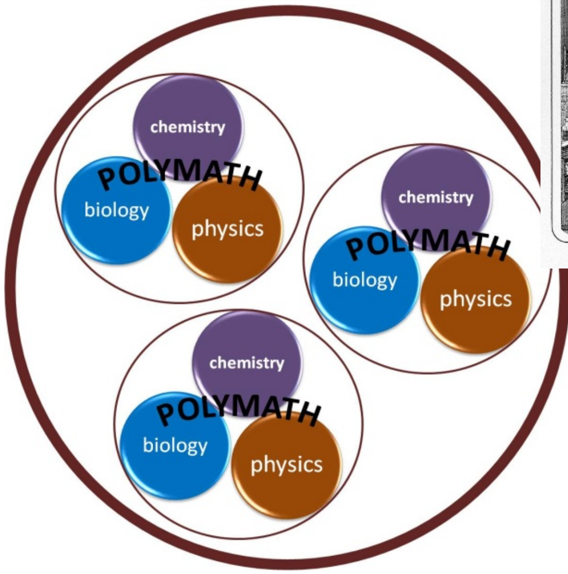
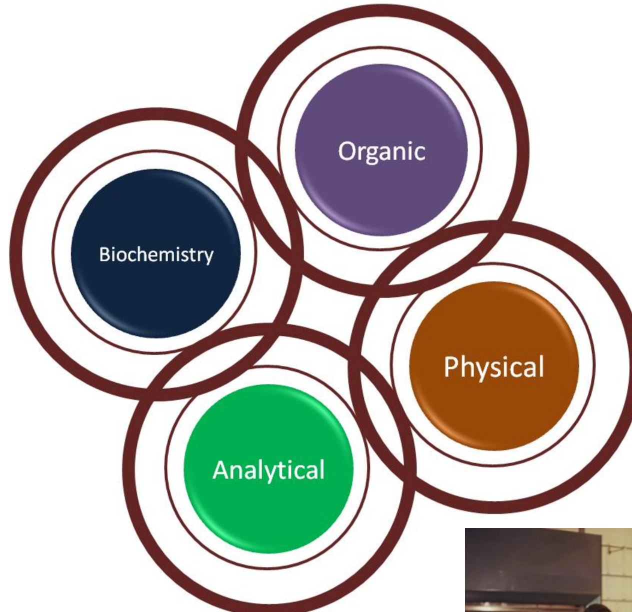
Driving Factors for Safety Education in the 21st Century

- 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

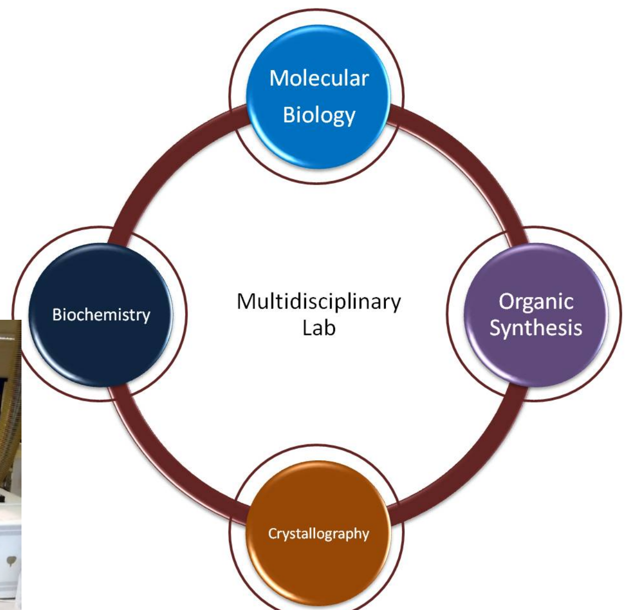
The Changing Research Environment





Late 19th & Early 20th

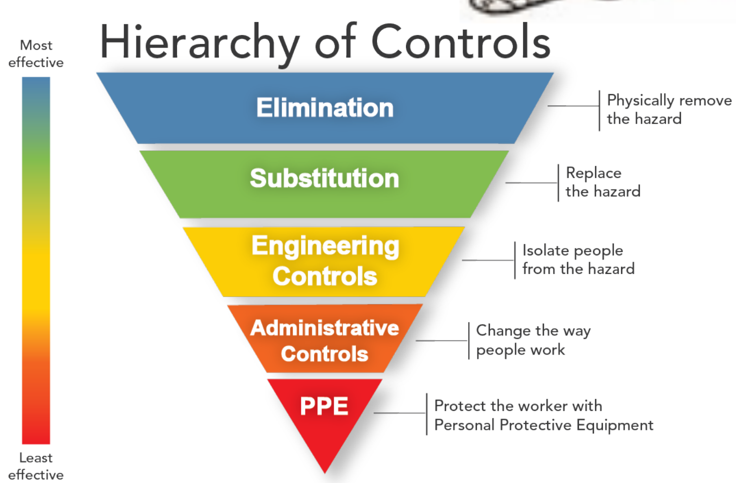
Mid 20th



Late 20th & Early 21st

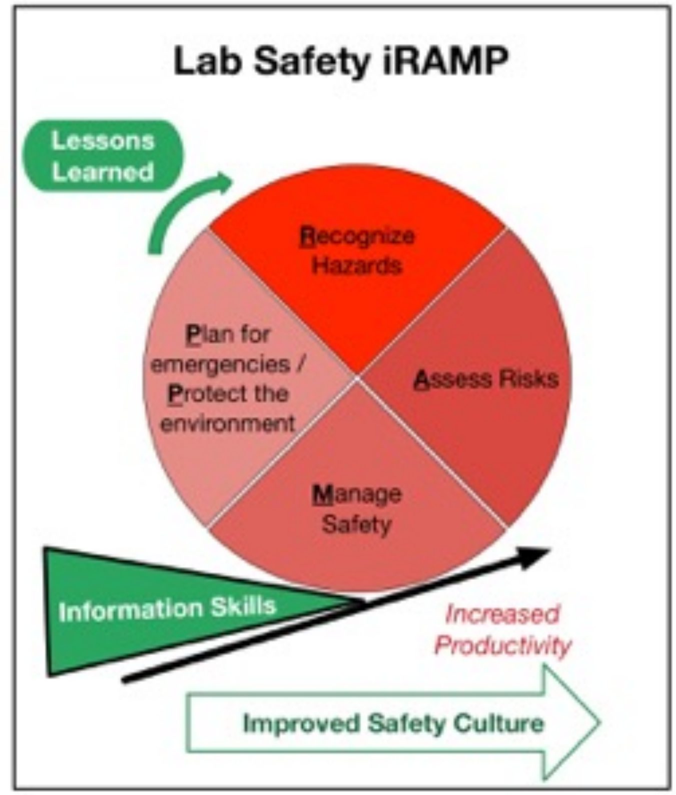
Moving Lab Safety Into the 21st Century

Identify Hazards from previous events



20th Century
Training & Controls selected based on Rules + Chemical Intuition

Change through Safety Education



21st Century
Safety systems based on education, improved culture, and documented Risk Assessment

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

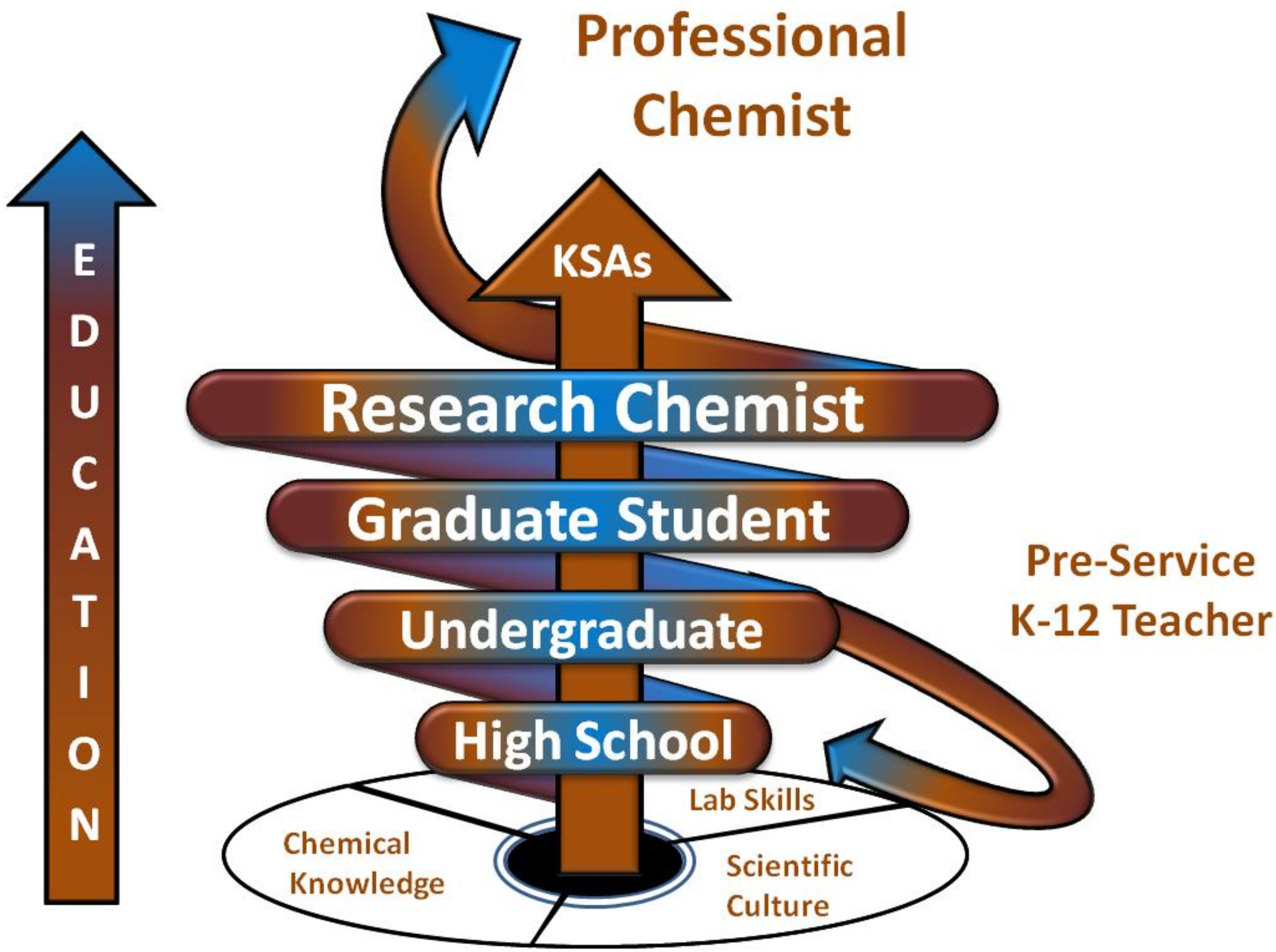
The Spiral Approach

- 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



KSA Development by Learner Group

Educational Stage	Knowledge	Skills	Cultural Aspects
Professional Chemist	Identify and estimate significance of emerging risks	Make risk decisions and teach risk assessment	Accountable for group performance
Graduate Researcher	Develop procedures with reducing risks in mind	Use Risk Assessment tools to propose risk levels for review	Oversee others' safety practices
Mentored Researcher (UG, CURE, REU, etc.)	Review procedures; locate information to identify hazards	Learn to use Risk Assessment tools	Raise questions and concerns related to risk
High School Student	Learn RAMP Principles; understand rules	Select Applicable Rules	Respect Rules

Methodology & Tools

Learning

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
7. Washington, DC – October 30, 2015
8. Perth Amboy, NJ – May 24, 2017


CSB Safety Bulletin

U.S. Chemical Safety and Hazard Investigation Board

October 2014

Key Lessons for Preventing Incidents from Flammable Chemicals in Educational Demonstrations

Eliminating Flash Fire Hazards by Substituting or Minimizing the use of Flammable Chemicals and Performing an Effective Hazard Review Will Prevent Injuries

Key Lessons Summarized:

- Due to flash fire hazards and the potential for serious injuries, do not use bulk containers of flammable chemicals in educational demonstrations when small quantities are sufficient
- Employers should implement strict safety controls when demonstrations necessitate handling hazardous chemicals — including written procedures, effective training, and the required use of appropriate personal protective equipment for all participants
- Conduct a comprehensive hazard review prior to performing any educational demonstration
- Provide a safety barrier between the demonstration and the audience

CSB • Key Lessons for Preventing Incidents from Flammable Chemicals in Educational Demonstrations

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?

<u>Just a few of the Topics of Relevance:</u>

- 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]

[2]Sigmann, S.B.; McEwen, L.R. Teaching Chemical Hygiene and Information Skills Using Risk Assessment. In *Integrating Library and Information Literacy into Chemistry Curricula*; Lovitt, C.F.; Shuyler, K.; Li, Y, Eds; ACS Symposium Series; American Chemical Society: Washington DC, 2016; 1232, pp 57–92.

Student Engagement in Safety

Chemical Hazards – Metal Compounds

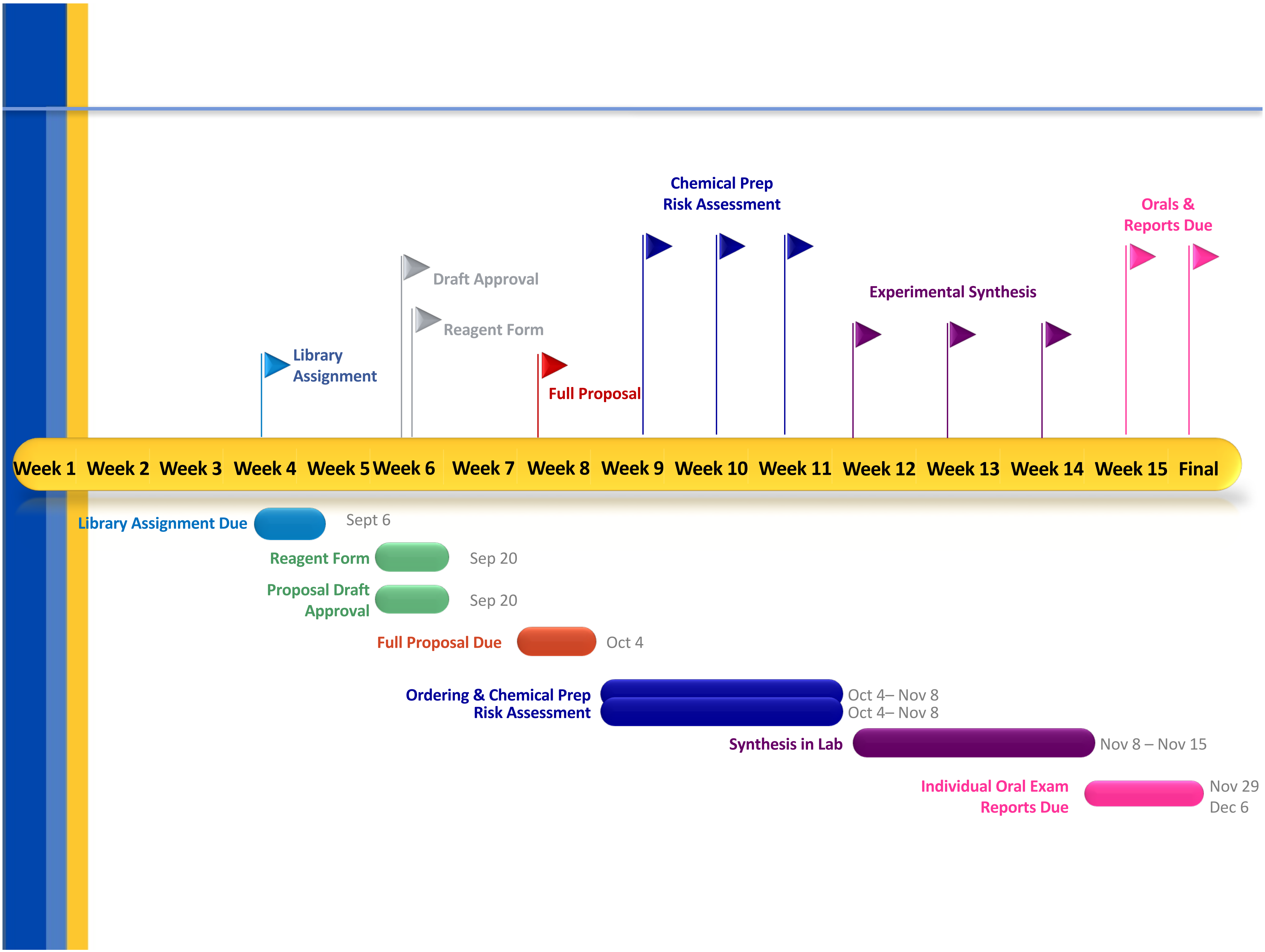
Complex	CAS	Formula	8 hour TWA or Ceiling
cobalt(II) carbonate	57454-67-8	$CoCO_3 \cdot xH_2O$	0.02 mg/m^3
palladium(II) chloride	7647-10-1	$PdCl_2$	No Data
aluminum sulfate octadecahydrate	7784-31-8	$Al_2(SO_4)_3 \cdot 18H_2O$	2 mg/m^3
chromium(III) chloride	10025-73-7	$CrCl_3$	0.5 mg/m^3
copper(II) sulfate pentahydrate	7758-99-8	$CuSO_4 \cdot 5H_2O$	1 mg/m^3
nickel(II) nitrate hexahydrate	13478-00-7	$Ni(NO_3)_3 \cdot 6H_2O$	0.015 mg/m^3 0.10 mg/m^3
iron(III) chloride hexahydrate	10025-77-1	$FeCl_3 \cdot 6H_2O$	1.0 mg/m^3
vanadium(IV) oxide sulfate hydrate	123334-20-3	$VOSO_4 \cdot xH_2O$	0.050 mg/m^3 *
mercury(II) oxide	21908-53-2	HgO	0.025 mg/m^3
yttrium(III) nitrate hexahydrate	13494-98-9	$Y(NO_3)_3 \cdot 6H_2O$	1.0 mg/m^3
potassium permanganate	7722-64-7	$KMnO_4$	0.2 mg/m^3

NIOSH
NIOSH*Ceiling
ACGIH TLV

Acetyl Acetone

GHS	
 **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!"



Chemical Prep
Risk Assessment
Orals &
Reports Due
Draft Approval
Experimental Synthesis
Reagent Form
Library
Assignment
Full Proposal
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Week 11
Week 12
Week 13
Week 14
Week 15
Final
Library Assignment Due
Sept 6
Reagent Form
Sep 20
Proposal Draft
Approval
Sep 20
Full Proposal Due
Oct 4
Ordering & Chemical Prep
Risk Assessment
Oct 4– Nov 8
Oct 4– Nov 8
Synthesis in Lab
Nov 8 – Nov 15
Individual Oral Exam
Reports Due
Nov 29
Dec 6

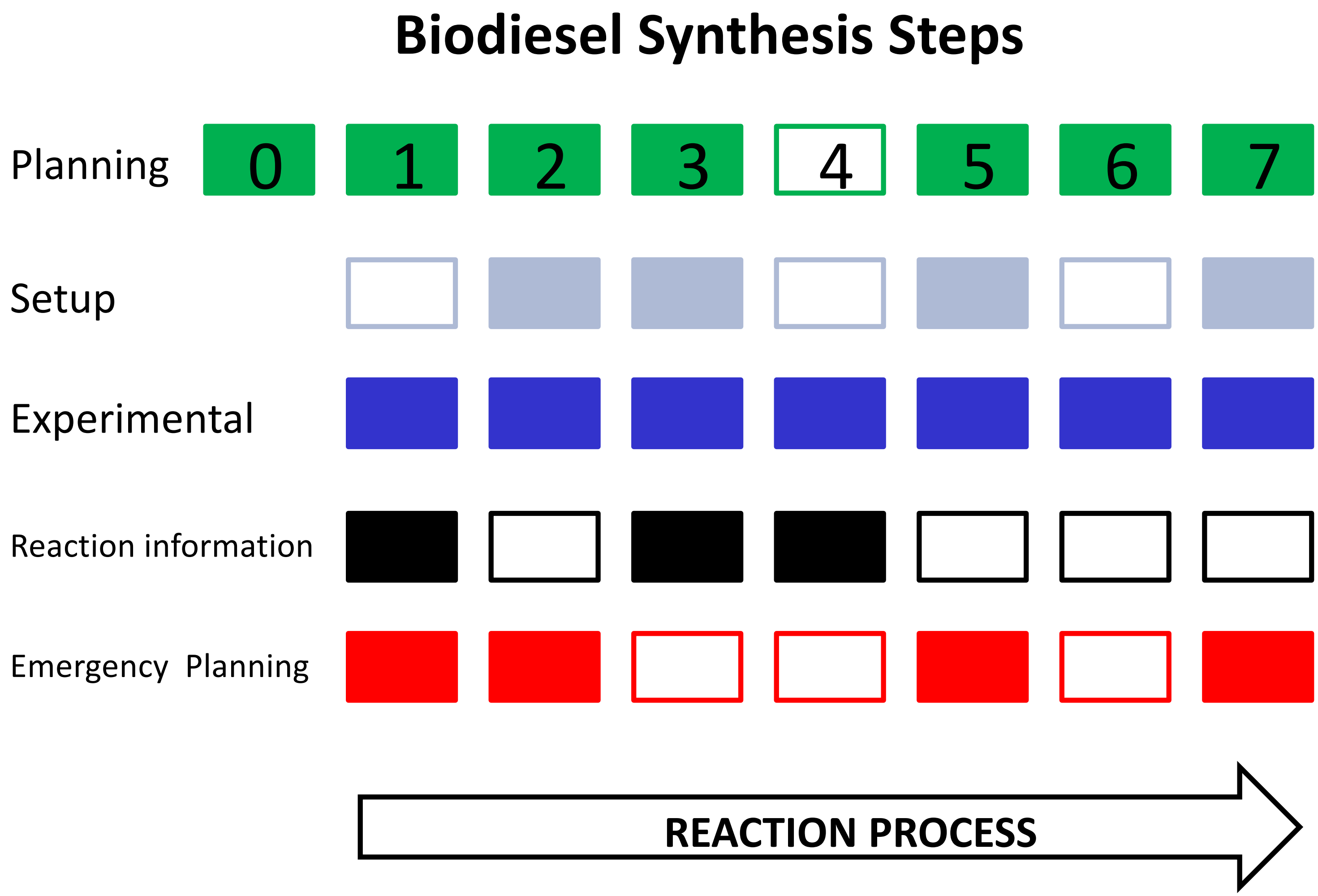
Novel Implementations in Research Labs

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



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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

NOTES: Syringe transfer

Reagents
Hydrogen chloride solution (4 N HCl in 1,4-dioxane)

DANGER

Recommended glove material: Chloroprene

Flash point 17 °C (63 °F)
Conditions to avoid
Heat, flames and sparks.

Reagents
Canola Oil

Recommended glove material: Nitrile

Not classified Hazardous by GHS

> 93.3 °C (200.0 °F)Closed Cup
Conditions to avoid
Heat, flames and sparks.

Reagents
Methanol

Recommended glove material (splash): Nitrile

DANGER

Initial boiling point and boiling range 64.7 °C (148.5 °F) - lit.
Flash point 9.7 °C (49.5 °F) - closed cup

Conditions to avoid
Heat, flames and sparks.

Product Number : 179957
Brand : Sigma-Aldrich
CAS-No. : 67-56-1

Experimental

1. **Combine in 50 mL round bottom flask (RBF)**

Controls for Failed Barriers

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

Electronic Notebooks

"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?"

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

"I like your checklist idea. I will incorporate that in the lab journal."

Combining Training & Education

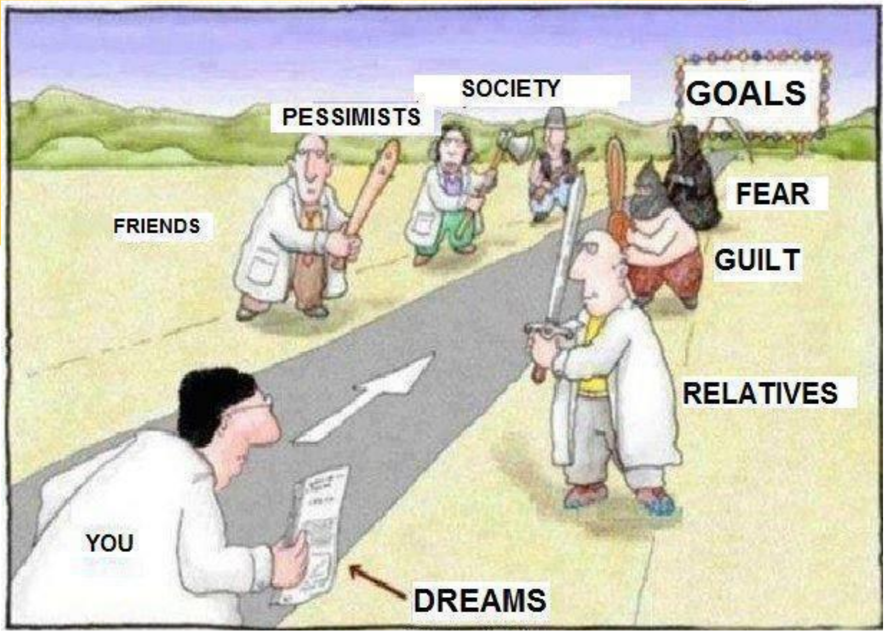
2017 Summer Research Course (Funded)

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



SOCIETY
GOALS
PESSIMISTS
FEAR
FRIENDS
GUILT
RELATIVES
YOU
DREAMS

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???