# LAYERS OF TOXICOLOGY EDUCATION IN AN UNDERGRADUATE CURRICULUM

GREEN CHEMISTRY | sdsu

**Douglas Raynie and David Cartrette**

douglas.raynie@sdstate.edu
Department of Chemistry and Biochemistry
South Dakota State University

# CHEM 484 “Chemical Toxicology”

Offered since 2012-2013

Course Description:  Understanding of the principles of toxicity, including the molecular basis for toxicity and the fate and transport of chemicals in the environment.

# COURSE OUTLINE

Fundamentals of Toxicology
- Terminology
- Toxicodynamics/Dose-Response Relationships
- Classes of Toxicants
- Legal and Regulatory Issues

Toxicity Mechanisms and Actions
- Absorption, Distribution, Metabolism, and Excretion
- Acute Toxicity
- Carcinogenesis, Mutagenesis, Teratogenesis

Environmental Toxicology
- Risk Assessment
- Bioaccumulation and Degradation
- Transport and Fate of Toxicants in the Environment

# ACS-CEI Award for Incorporation of Sustainability into Chemical Education

# Our New Initiative

Honors/Majors Curriculum

Modified 1-2-1 curriculum. Second semester (freshmen) is first organic course.

Academic Affairs Scholarly Excellence Grant

Introduce toxicology into first honors/majors organic course via three lectures on toxicology fundamentals, EPI Suite exercise, and bioassay laboratory.

# Sample of toxicological principles described and discussed:

- Stereochemistry and Thalidomide
  - ✓ exposure, dose, dose/response
- Development of Teflon and Halogenated Compounds
  - ✓ environmental exposure, remediation, chemical disposal hazards
- Grilling Food and Polycyclic Aromatic Compounds
  - ✓ exposure routes, biological response, toxicokinetics/toxicothermodynamics

# Toxicological terminology introduced in lecture and applied in lab

- Substance
- Dose
- LD 50
- ADI – acceptable daily intake
- Bioaccumulation
- Acute exposure vs. chronic exposure
- Dose/Response curve

# Laboratory Exercise

Week 1 Pre-lab Activity

- Read New York Times article on increasing incidence of vitamin toxicity due to overconsumption of supplements and fortified foodstuffs
- Consult toxicological database (EPI Suite) for toxicological information on common vitamins: A, B12, C, D, E, and K
- Calculate toxic dosage of A, D, E, and K for their body weight
- Review article on vitamin metabolism and its effects on the liver
- Answer a series of questions related to vitamin toxicity, the NYT article, etc.

# Week 1 Activity

- 30 to 45 minute discussion about answers to these questions and any supplemental online research completed
  - Greater interest in the topic
  - Applications to themselves (Is my diet poor, having to eat college food? Do I need to do something to fix that?)
  - No great changes noted by students in vitamin advertising (but most don't watch commercial television anymore)
  - Large portion of discussion revolved around who to trust about what claims are made
- Guiding Question: There is no known UL of Vitamin K. Based on dose/response curves, what is your recommendation?

# Laboratory Exercise

Week 1 Experimental

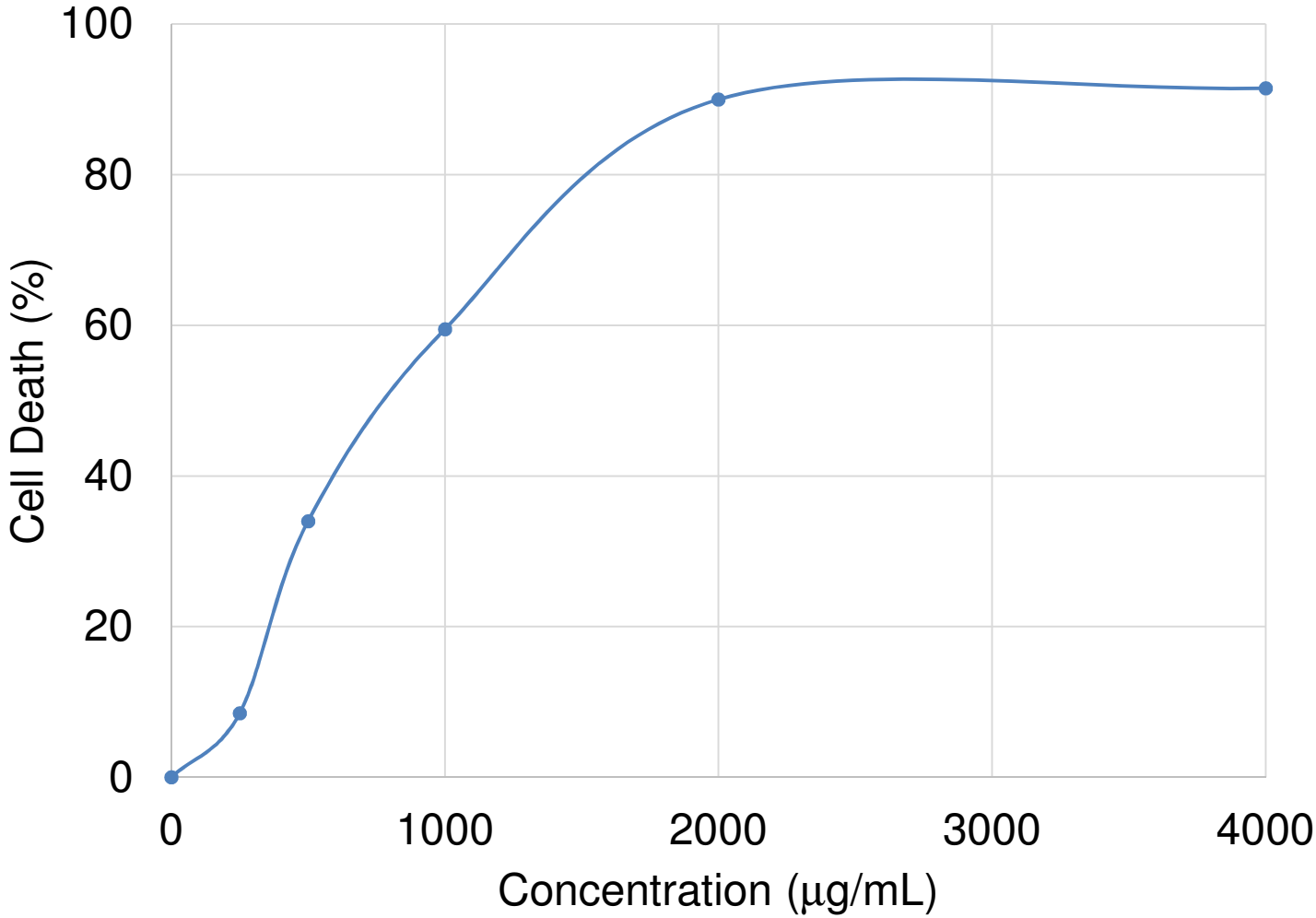
- Prepare solutions of each fat-soluble vitamin
- Create a broth of healthy hepatic cells and measure concentration
- Inoculate samples of hepatic cell broth culture with vitamin solutions
- Incubate for 1 week

# Laboratory Exercise

Week 2

- Retrieve inoculated hepatic cell broth solutions
- Complete colorimetric assay (e.g., MMT or LDH) to determine cell survival/death ratio
- Upload each lab section's data on course website
- Data analysis
- Draw conclusions about toxicological effects of fat-soluble vitamins on hepatic cells

# Sample Data – Vitamin A Toxicity



# Student Conclusions

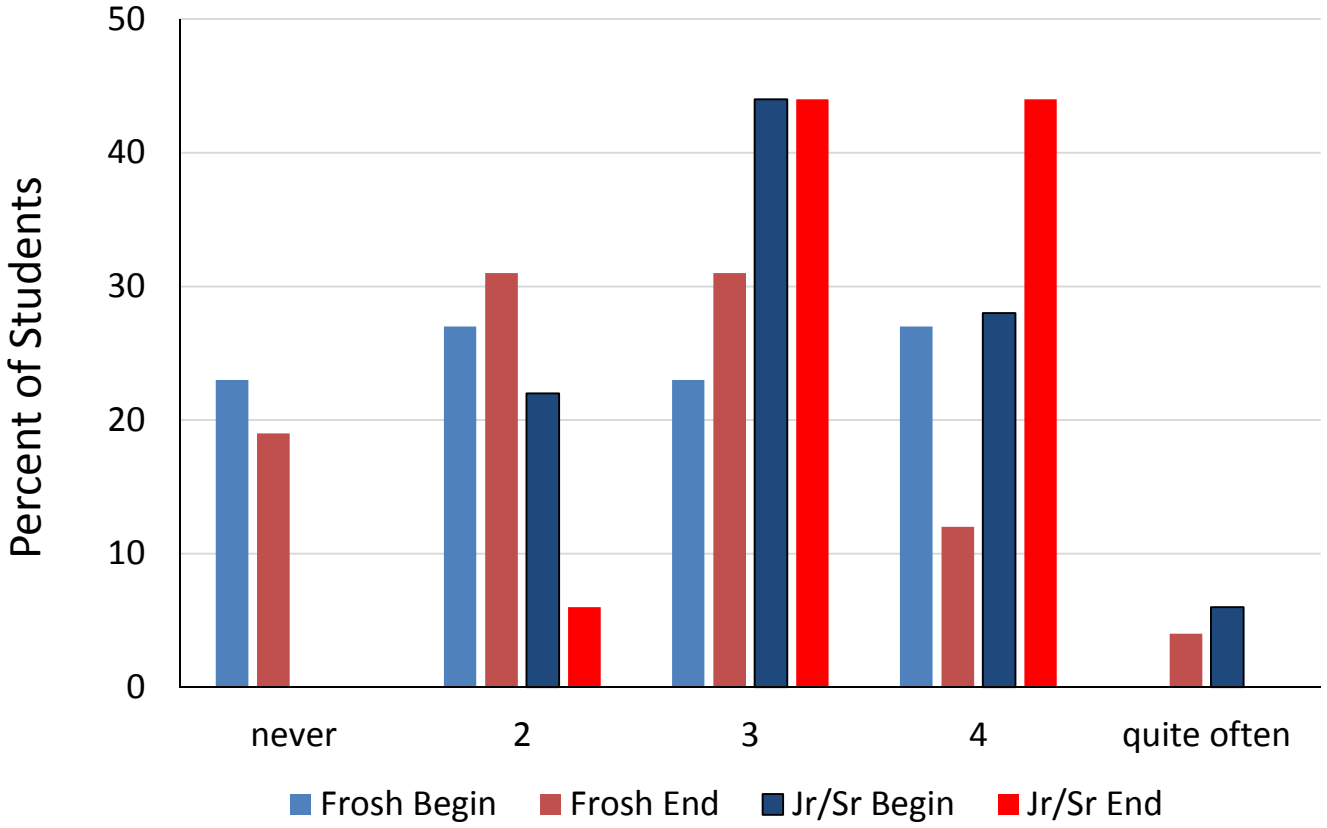
- Dose/Response curve inconclusive regarding Vitamin K
- Requires better variable control
  - ✓ Number of trials
  - ✓ Smaller gaps in vitamin concentration
  - ✓ Different cell lines (cancerous vs. non-cancerous)
  - ✓ Include water soluble vitamins
- Critical thinking skills improved
  - ✓ Better able to critique articles (scholarly and popular)
  - ✓ Questioned some methods in articles
- Knowledge of toxicology increased
  - ✓ Terminology usage in lab and lecture

# Instructor Conclusions

- Students very engaged
- High motivation to investigate further
- Most indicated they would take ChemTox as a result of this experience

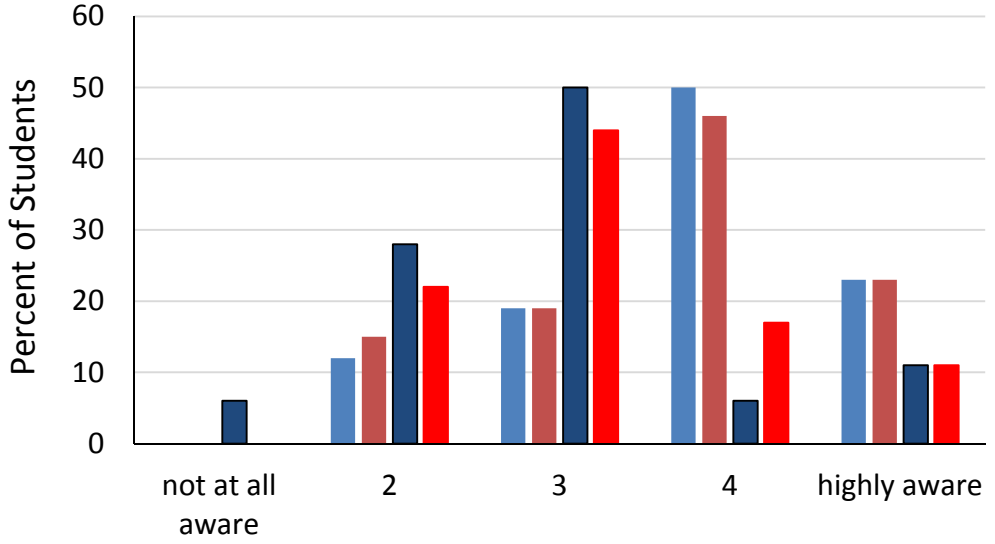
# Student Survey

Have you ever been concerned about the harmful effects of the chemicals you have used in any of your laboratory experiments while at SDSU?

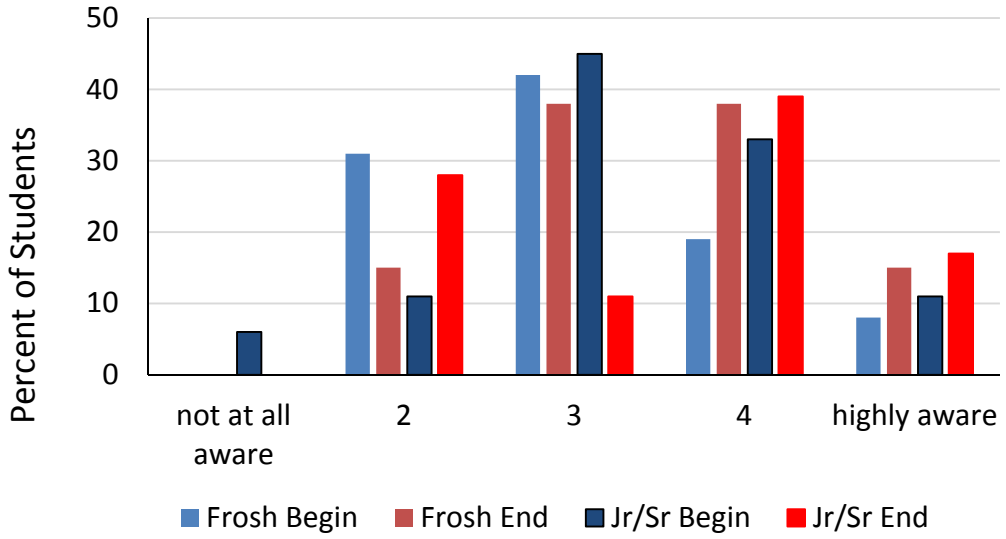


# Student Survey

In your opinion, how aware are chemists of the inherent hazard associated with a chemical?

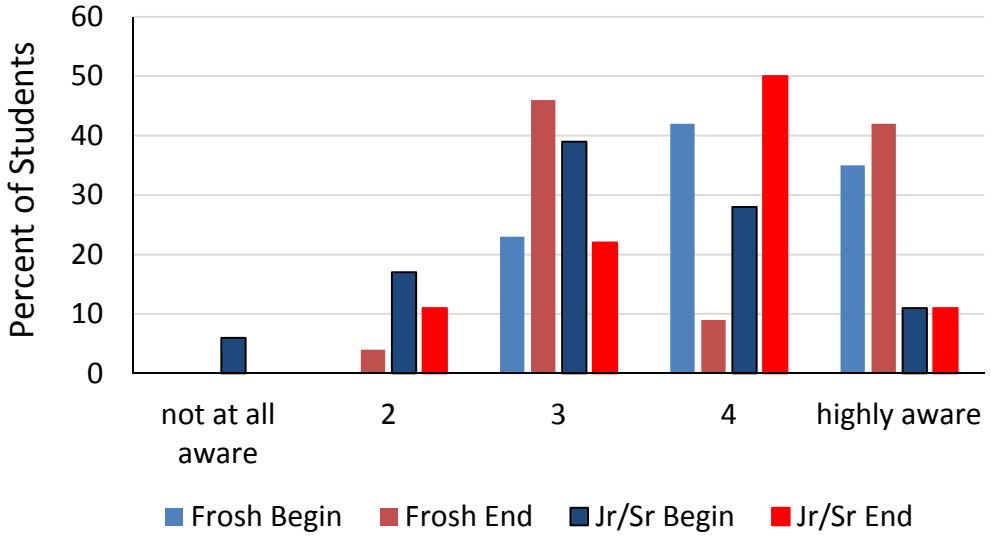



How aware are you personally of the inherent hazard with the chemicals you used in your classes or in research laboratories you may have worked?

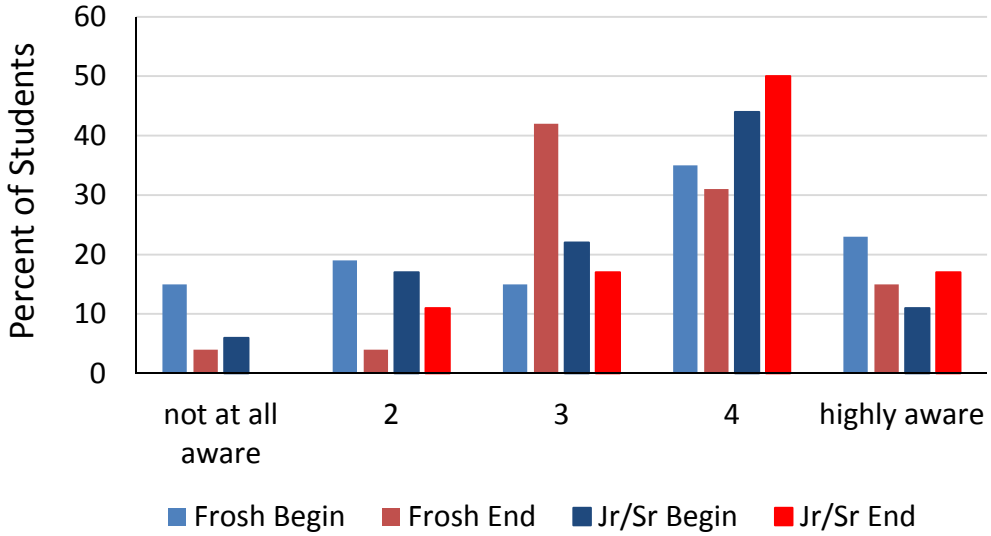


# Student Survey

In your opinion, how aware are chemists of ways to minimize their exposure to hazardous chemicals in the laboratory?

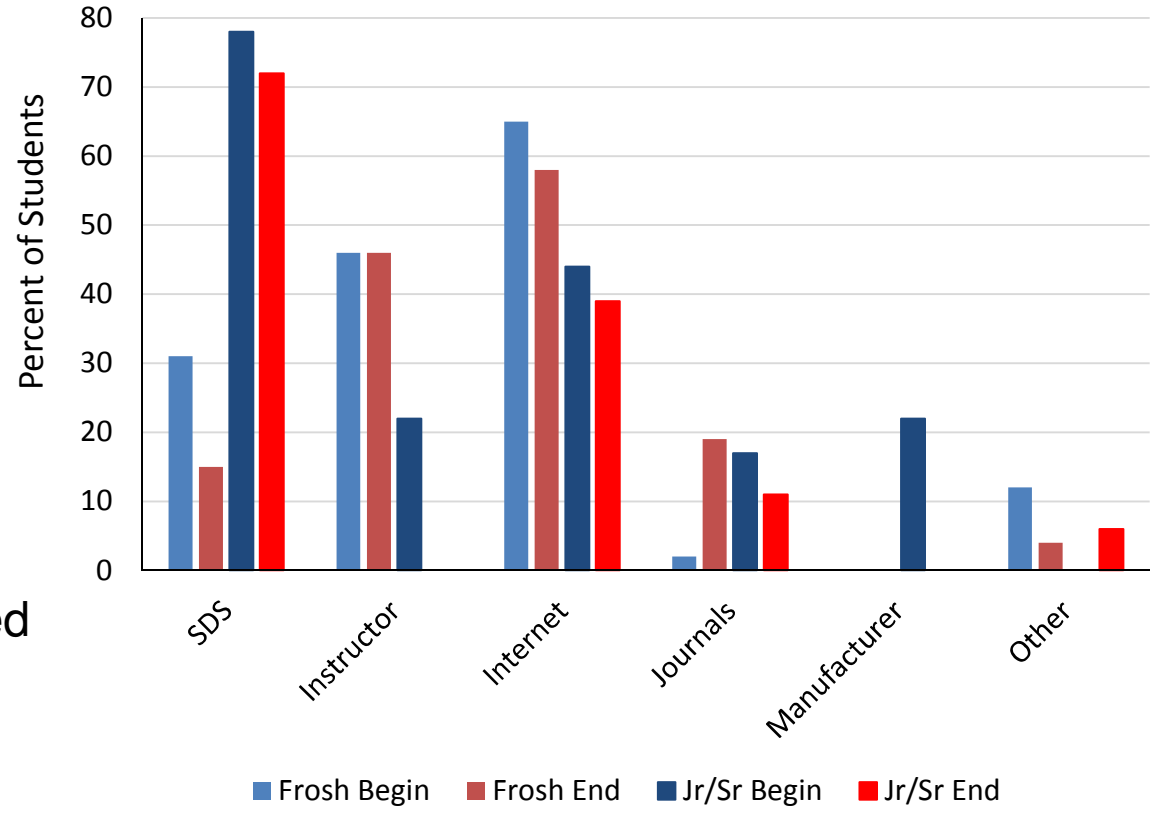



How aware are you personally of the ways to minimize your exposure to hazardous chemicals in your classes or in research laboratories you may have worked?



# Student Survey

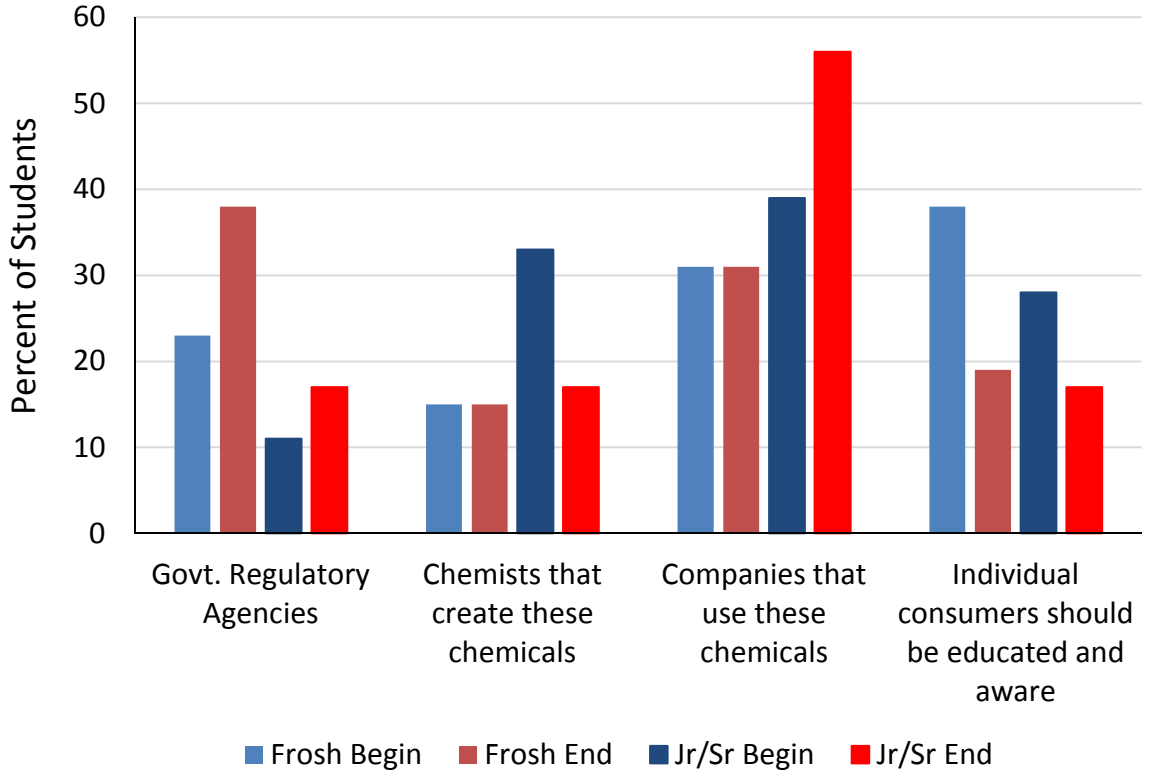
If you desire to find out more information about the toxic effects of a specific chemical, how would you proceed?




Note for Jr/Sr:
22% at beginning and 83% at ending specifically mentioned NIH or similar toxicology databases

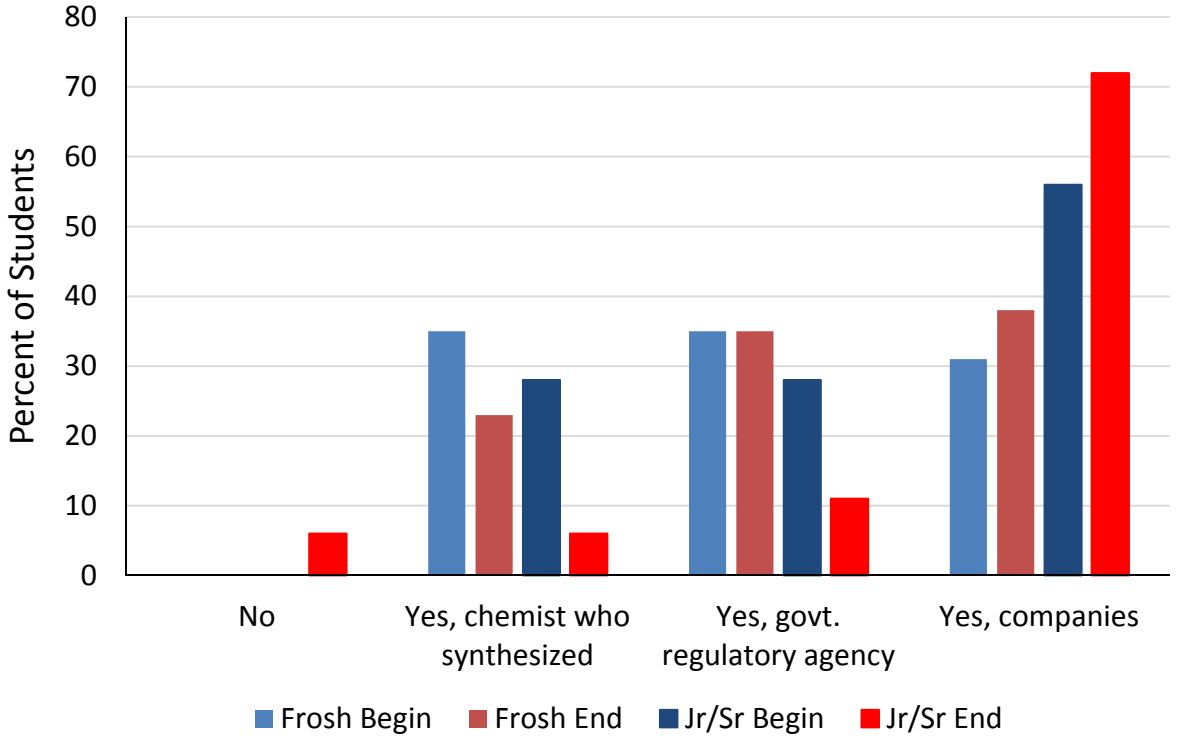
# Student Survey

Common products we use every day contain chemicals that are known, or suspected, to have toxic effects. In your opinion, who is most responsible for minimizing the toxic hazard and/or exposure of the public to these chemicals?



# Student Survey

Common products we use every day contain chemicals that are known, or suspected, to have toxic effects. In many cases, a company wishes to use a chemical for which that have only limited knowledge of the toxic effects. Should the toxicity of a chemical be well-characterized before it is used in a consumer product and, if so, who should have the responsibility for performing this characterization?

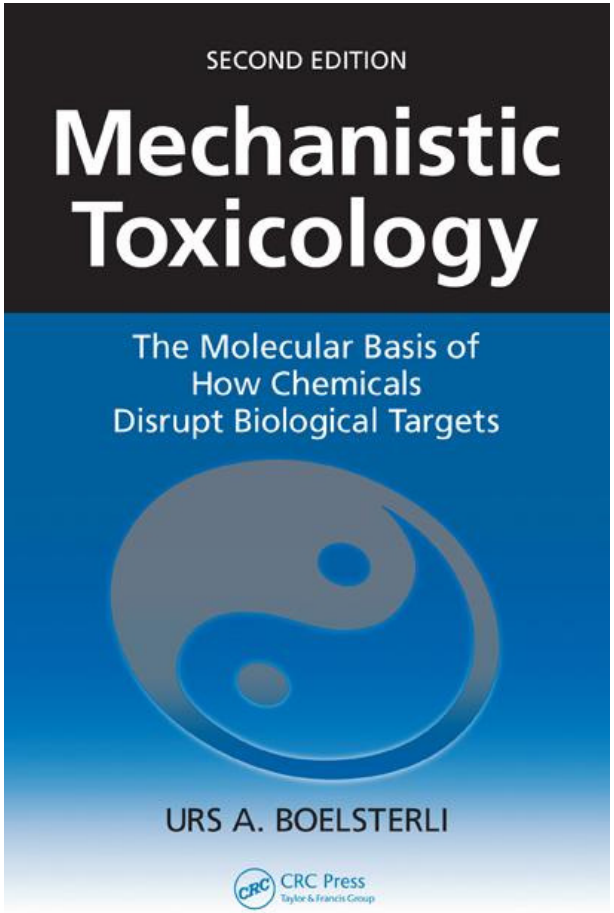


# Survey Results

- Students have increased concern regarding chemicals used at SDSU
- Students increased their awareness of chemical hazards
- Students more knowledgeable of how to avoid/minimize chemical exposure

# Shift Emphasis of Chemical Toxicology

- Current media
  (*Above The Fold*)
  discussion
- EPI Suite Activity
- Small Group Project
- *This I Believe* Essay



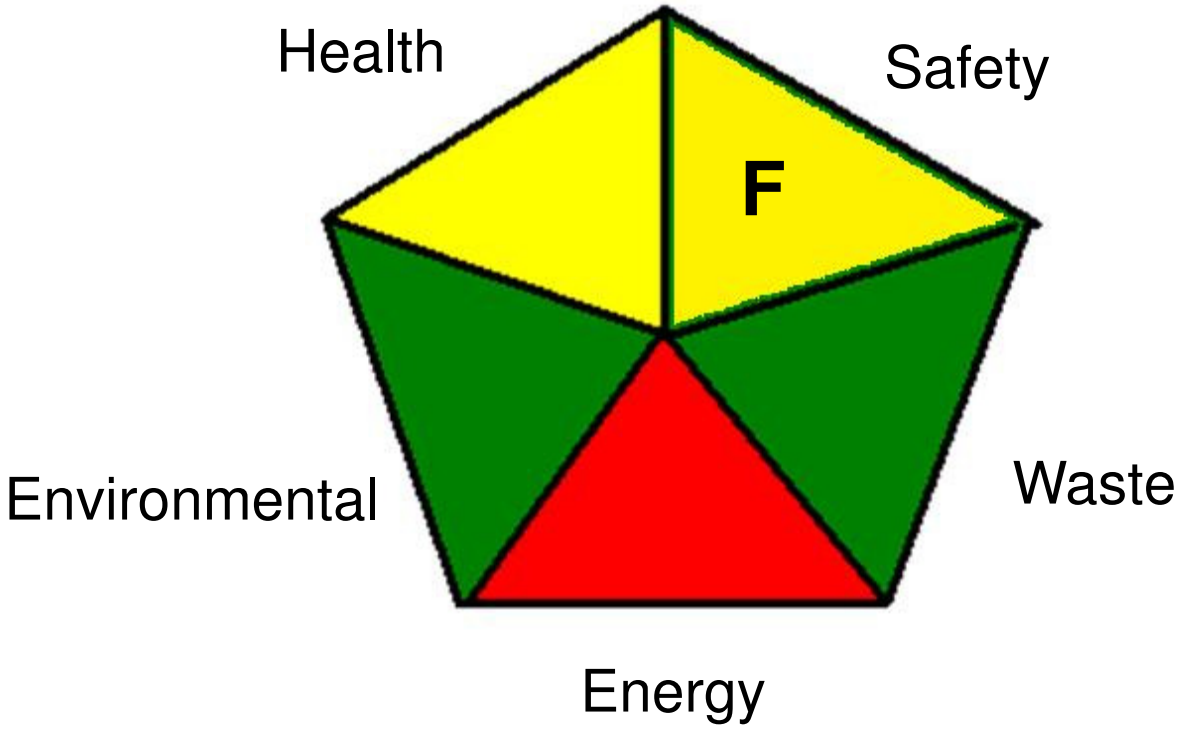
# Sample Small Group Projects

- Disposal of Pharmaceuticals
- Pregnancy/Lab Manuals
- Animas River Spill

# Moving Toxicology into Other Courses

- Second Semester Organic
  - ✓ Synthesis of drug compound, brine shrimp assay
  - ✓ EPI Suite activity
- Analytical
  - ✓ Green chemistry assessment
  - ✓ Extraction and analysis of environmental toxin
- Environmental Chemistry

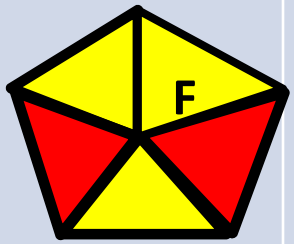
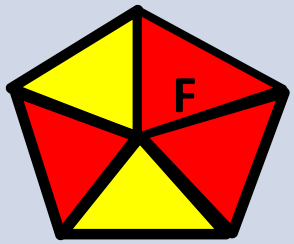
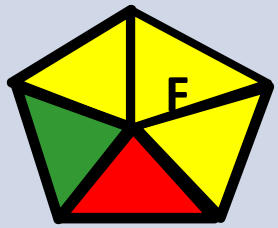
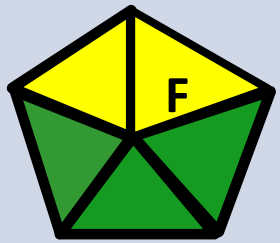
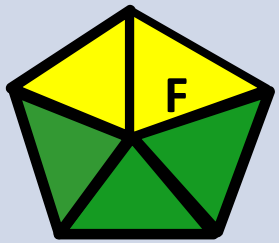
# Green assessment - profile



# NEMI methods for PAH in water

| Method | Chemicals | | Energy uses | Waste |
|---|---|---|---|---|
| 550 | Sodium Thiosulfate<br>Methylene chloride | Acetonitrile<br>Sodium Sulfate | Evaporating 200 mL organic solvent<br>LC | 335 g |
| 610 | Sodium thiosulfate<br>Methylene chloride<br>Acetonitrile<br>Sodium sulfate | Cyclohexane<br>Pentane<br>Methanol<br>Acetone | Evaporating 200 mL organic solvent<br>GC | 290 g |
| 525.2 | Methylene chloride<br>Methanol<br>Sodium sulfate<br>Toluene | Ethyl acetate<br>Acetone<br>HCl, 6N | Evaporating 10 mL organic solvent<br>GC-MS | 52 g |
| 70620 | Methanol<br>HCl, 1.0N | | immunoassay | 1.2 g |
| A00156/ A00157 | Sulfuric acid, 2M<br>Methanol | | immunoassay | 4.3 g |

# Method comparison

| 550 | 610 | 525.2 | 70620 | A00156/A00157 |
|---|---|---|---|---|
|  |  |  |  |  |

# Conclusion

Working toxicology material into existing course content provides an alternative to the addition of more coursework and helps develop an awareness of toxicological implications as part of the normal practice of chemistry.