Undergraduate Educator Network Webinar Series

Adopting the Undergraduate Toxicology Learning Framework

Sponsored by
Undergraduate Education Subcommittee
SOT Education Committee

April 29, 2019
12:00 Noon (ET)

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Welcome

Christine Perdan Curran, PhD
Chair, Undergraduate Subcommittee
Speaker
Northern Kentucky University

Joshua Gray, PhD
Speaker
US Coast Guard Academy
Speakers

- **Joshua Gray**, Introduction to Vision and Change and Modifying an Existing Undergraduate Toxicology Course Using the Toxicology Learning Framework

- **Chris Curran**, Applying Toxicology Learning Framework in Toxicology and Non-toxicology Lab and Lecture Courses
Questions and Comments

- Please participate.
- Send to “All Panelists” via the Q&A panel in the lower right.
Adopting the Undergraduate Toxicology Learning Framework

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Extended protocols available in SOT Undergraduate Resource Curriculum Library
www.toxicology.org
Overall Objectives

- To familiarize the audience with Vision and Change, CourseSource, and other teaching resources related to the Undergraduate Toxicology Learning Framework.
- To demonstrate how the Undergraduate Toxicology Learning Framework can be used to design courses.
Objectives

- Demonstrate the Vision and Change and available resources for undergraduate toxicology educators
- Provide example of adoption of the Undergraduate Toxicology Learning Framework for a one semester elective undergraduate toxicology course focused on human health
Vision and Change

- 2011 report catalyzed change in undergraduate biology education
- Centered Biology education for ALL learners, including non-majors
- Focus on evidence-based teaching practices
- Core Concepts and Core Competencies that underlie all of undergraduate biology

www.visionandchange.org
Vision and Change Core Concepts and Core Competencies

<table>
<thead>
<tr>
<th>Core Concepts</th>
<th>Core Competencies</th>
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</thead>
<tbody>
<tr>
<td>Evolution</td>
<td>Apply the process of science</td>
</tr>
<tr>
<td>Structure and Function</td>
<td>Use quantitative reasoning</td>
</tr>
<tr>
<td>Information</td>
<td>Employ modeling and simulation</td>
</tr>
<tr>
<td>Energy</td>
<td>Experience interdisciplinary science</td>
</tr>
<tr>
<td>Systems</td>
<td>Communicate with other disciplines</td>
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<td>Integrate science and society</td>
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</table>
## Course Titles

<table>
<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>Anatomy-Physiology</td>
<td>Biochemistry and Molecular</td>
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<td>Biology</td>
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<td>Bioinformatics</td>
<td>Cell Biology</td>
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<tr>
<td>Developmental Biology</td>
<td>Ecology</td>
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<tr>
<td>Evolution</td>
<td>Genetics</td>
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<tr>
<td>Immunology</td>
<td>Introductory Biology</td>
</tr>
<tr>
<td>Microbiology</td>
<td>Neurobiology</td>
</tr>
<tr>
<td>Plant Biology</td>
<td>Science Process Skills</td>
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</tbody>
</table>

Coming soon! Toxicology
## Example Core Concepts

<table>
<thead>
<tr>
<th>Vision and Change Core Concepts for Undergraduate Biology</th>
<th>Foundational Concepts for Biochemistry and Molecular Biology</th>
<th>Core Concepts for Undergraduate Toxicology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evolution: The diversity of life evolved over time by processes of mutation, selection, and genetic change.</td>
<td>Evolution &amp; Homeostasis</td>
<td>Evolution: Evolution drives the interplay between toxicants/toxins and xenobiotic defense mechanisms and justifies the use of model organisms.</td>
</tr>
<tr>
<td>Structure and Function: Basic units of structure define the function of all living things.</td>
<td>Energy is required and transformed in biological systems.</td>
<td>Pathways and Transformations of Energy and Matter: Interaction of toxicants with organisms are described through paradigms in dose-response, ADME, and toxicoc-/pharmacokinetics.</td>
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### Core Concepts for Toxicology

**Evolution:** Evolution drives the interplay between toxicants/toxins and xenobiotic defense mechanisms and justifies the use of model organisms.

**Biological Information:** Differences in genomes and environmental exposure drive differences in susceptibility and responses to toxicants.

**Risk Assessment and Risk Management:** Epidemiology and historical events together with science drive regulatory responses to risk to individuals and the environment.

**Systems Toxicology:** Toxicants affect cellular, organ, individual, and ecological systems.

**Pathways and Transformations of Energy and Matter:** Interaction of toxicants with organisms are described through paradigms in dose-response, ADME, and toxico-/pharmacokinetics.
Undergraduate Toxicology Learning Framework—Overall Design

- Level 1—Core Concepts
- Level 2—Toxicology Concepts
- Level 3—Learning Objectives
- Level 4—Example Learning Objectives and Case Studies
Example

- Level 1–Evolution
- Level 2–Model Organisms for Toxicology
- Level 3–Describe Features of Ideal Model Organisms
- Level 4–
  - Explain how large numbers of offspring are beneficial for ideal model systems.
  - Explain how some model organisms are selected for organ-specific similarity to humans, for example, skin of pigs.
  - Describe which ideal model organisms have similar xenobiotic metabolism systems to humans.
Undergraduate Toxicology at the US Coast Guard Academy

- No Physiology or Anatomy is offered
  - Physiology takes up a portion of the classes
- Organic Chemistry and Biochemistry are not prerequisites
- Junior/Senior level elective course
- Human health focus with minor coverage Environmental, Regulatory, Pharmaceutical
- Taught for 8 years
- Texts:
  - Principles and Practice of Toxicology in Public Health–Richards and Bourgeois
  - Basics of Toxicology–Kent
  - Anatomy and Physiology coloring books (cheap and quite detailed!)
## 40 Lectures, Three Exam Dates

<table>
<thead>
<tr>
<th>Lecture</th>
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<tbody>
<tr>
<td>1. Overview of Toxicology</td>
<td>21. Nephrotoxicity</td>
</tr>
<tr>
<td>2. Basic Physiology Introduction</td>
<td>22. Circulatory System</td>
</tr>
<tr>
<td>3. Cell Biology/Toxicity</td>
<td>23. Pulmonary Physiology</td>
</tr>
<tr>
<td>4-5. Dose-Response</td>
<td>24. Pulmonary Toxicology</td>
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<tr>
<td>6. ADME--Absorption</td>
<td>25. Neurobiology</td>
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<td>7. ADME--Distribution</td>
<td>26. Neurotoxicology</td>
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<tr>
<td>10-12. ADME--Biotransformation</td>
<td>29. Ocular Physiology and Toxicology</td>
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<td>15. Immune System</td>
<td>31. Developmental Tox</td>
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<td>16. Dermal Tox</td>
<td>32-33. Toxins</td>
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<tr>
<td>17. Hepatic Physiology</td>
<td>34. Regulatory Considerations</td>
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<tr>
<td>18. Hepatotoxicity</td>
<td>35. Toxicity Testing 1</td>
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<tr>
<td>19. Acetaminophen Case Study</td>
<td>36-37. Risk Assessment</td>
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Dose-Response 1–My Former Learning Objectives

• Draw a dose response curve, labeling the axes appropriately.
• Describe the features of a dose-response curve: threshold dose, quantitative relationship between dose and response, whether a causal relationship between cause and effect exists, and the relative toxicity of two compounds.
• Know the difference between the following doses: exposure, administered, absorbed, internal, and delivered.
• Given a dose response curve, identify regions where toxicity is occurring, not occurring.

• Given a dose response curve, explain the impact of a flatter or more vertical slope of the curve.
• Know that idiosyncratic reactions occur when a dose provides a response far outside from the others.
• Explain why dose is usually provided on a log scale.
• Explain and identify an LD50.
• Know the different time frames of exposure: acute (<24 h), subacute (<1 month), subchronic (1-3 months), and chronic (>3 months).
• Explain the following and be able to identify on a graph: LD50, ED50, TD50, NOAEL, LOAEL.
• Contrast a threshold toxicant with a nonthreshold toxicant.
• Explain why Margin of Safety is better than Therapeutic Index in terms of deciding whether a drug is beneficial or not.
• Explain the concept of dose spacing in terms of toxicity.
Step One: Map Toxicology Concepts (Level 2) Onto My Course

- Pathways and Transformations for Energy and Matter–Dose-Response
- Differences in Susceptibility to Toxicants (Dose-Response)
Step Two: Map Learning Objectives (Level 3)

- Core Concept: Pathways and Transformations for Energy and Matter
- Toxicology Concept: Dose-Response
  - Describe the different protocols for dosing: exposure time, administration, absorption, absorbance, internal, and delivered.
  - Describe a dose-response curve, labeling the axes and identifying the important regions of the plot.
  - Describe the features of a dose-response curve.
  - Explain differences in dose-responses in a population of individuals.
  - Describe why individuals who have idiosyncratic responses are outliers.
  - Describe how alterations in homeostasis can affect an individual’s dose-response.
  - Two more…
Step Two: Map Learning Objectives (Level 3)

- Core Concept: Biological Information
- Toxicology Concept: Differences in Susceptibility to Toxicants (Dose-Response)
  - Explain how differences in individuals result in differences in susceptibility of a population to toxicants.
  - Explain why inbred animals are used in many toxicological tests.
  - Contrast idiosyncratic reactions with other kinds of variation in a population’s response to a toxicant.
  - Contrast Margin of Safety with Therapeutic Index with regards to prediction of drug safety in a population.
  - Describe the concept of dose spacing in terms of toxicity.
  - Describe the concept of hormesis as it applies to toxicology.
Step Three: Choose Learning Objectives and Case Studies (Level 4)

- Choose topics related to the course you are teaching
  - For example, I might choose the case study focused on penicillin’s idiosyncratic reaction to talk about dose-response curve outliers and their significance.

- Repeat this process for all days of the course
Step Four: Evaluate any Missing Toxicology Concepts (Level 2)

- Which Toxicology Concepts are not currently taught in my class? Where can I add them? Do I want to include them?
Step 5: Closing the Loop

- Make sure each Toxicology Concept reinforces the overall Core Concept
- Share your mapped course with others via lifescitrc.org
- Develop new case studies or exercises and submit them to CourseSource for publication.
Summary

- Discussed Vision and Change and how the Undergraduate Toxicology Learning Framework integrates with other biology courses using the V&C paradigm
- Outlined a process for mapping the Undergraduate Toxicology Learning Framework onto an existing Toxicology course
Questions and Comments

- Please participate.
- Send to “All Panelists” via the Q&A panel in the lower right.
Applying the Framework in Toxicology and Non-Toxicology Lab and Lecture Courses

Christine Perdan Curran
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curranc1@nku.edu
Objectives

- Demonstrate how the Learning Framework can be used in toxicology and non-toxicology courses.
- Provide strategies for efficiently incorporating multiple objectives in lectures and labs.
- Stimulate discussion and brainstorming on Learning Framework implementation.
## Review of Key Concepts from SOT Learning Framework

| Evolution: | Evolution drives the interplay between toxicants/toxins and xenobiotic defense mechanisms and justifies the use of model organisms. |
| Biological Information: | Differences in genomes and environmental exposure drive differences in susceptibility and responses to toxicants. |
| Risk Assessment and Risk Management: | Epidemiology and historical events together with science drive regulatory responses to risk to individuals and the environment. |
| Systems Toxicology: | Toxicants affect cellular, organ, individual, and ecological systems. |
| Pathways and Transformations of Energy and Matter: | Interaction of toxicants with organisms are described through paradigms in dose response, ADME, and toxico-/pharmacokinetics. |
Courses Taught

- Environmental Toxicology (lecture) Env350
- Evolutionary Neurobiology (lecture/lab) Bio402/L
- Neurosignaling (lecture/lab) Neu302/L
- Human Anatomy and Physiology (Bio208/L)
- Advanced Anatomy and Physiology (lecture/lab) Bio425/L

Biggest challenge: multi-section courses with rigid syllabi/curricula
Environmental Toxicology

- Able to apply all concepts easily by modifying lectures and activities

**Current Course Student Learning Objectives**

- Understand and apply scientific methods and principles of toxicology to identify and assess environmental risks across species and habitats.
- Identify key factors that increase susceptibility or resistance to toxins and toxicants.
- Appreciate the impact of human activities on natural systems.
- Connect evolutionary concepts with toxicology (e.g., pesticide resistance, toxin production).
- Develop scientifically sound arguments using the principles of risk assessment and risk management.
Some Lessons Cross Categories

Level 1: Evolution
Level 2: Evolution of toxins
Level 3: Explain the role of toxins in defense

Level 1: Biological information
Level 2: Gene-environment interactions
Level 3: Describe genetic polymorphisms that affect toxicokinetics and risk
Level 4: Identify allelic differences that alter the response to heavy metals
Sample Lecture Slides

- Start with plants when discussing resistance to metals

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**Figure 3:** Comparison of *B. juncea* and *B. juncea* transformed with either AtPCS or the evolved variant. Seedlings grown on media containing 150 μM CdCl₂.

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Cobbett C S Plant Physiol. 2000;123:825-832

Freeman et al. 2010
Plant Physiology
Building the Lesson

- Transitioning to animals shows convergent and divergent evolution.
- Metal-accumulating plants protect themselves but are toxic to many animals.
- All make and need anti-oxidants.
- Polymorphisms in these pathways affect susceptibility and resistance (EVOLUTION!).

Adapted from: Kumosani et al. 2008 Clinical Biochemistry 41 1199–1203
When In Doubt, Talk About Smoking
And Keep Talking About It!

**BaP**: polycyclic aromatic hydrocarbon
- Common air pollutant
- Also byproduct of grilling meat

**BPDE**: benzo[a]pyrene-9, 10-diol-epoxide
Adding More Levels

Level 1: Systems toxicology
Level 2: Cellular toxicology
Level 3: Describe sources of free radicals
Level 4: Explain free radicals and provide examples

Level 2: Organ-specific toxicology
Level 3: Recognize system and organ-specific toxic effects
Level 4: Provide examples of nephrotoxicity, etc. (cadmium in kidneys v. cadmium in bones)
Adding More Levels

Level 1: Pathways and Transformations
Level 2: Model organisms
Level 3: Role of xenobiotic defense mechanisms
Level 4: Explain Phase I and Phase II enzymes

Level 1: Risk and Risk Management
Level 2: Environmental toxicology
Level 3: Describe sources of heavy metal pollution
Level 4: Describe physiological and ecological effects of cadmium, arsenic, mercury
Environmental Toxicology Team Project

- Service learning project that includes risk assessment and risk management
- Work with local clients
- Application of knowledge leads to synthesis and mastery of toxicology lessons

ADVANTAGE: Incorporates multiple levels of learning objectives in a semester-long project
What if You Don’t Teach a Toxicology Course?

Evolutionary Neurobiology Lab

- Uses *C. elegans* (model organism)
- Exposed to various concentrations of chemicals (dose response)
- Where did chemoreceptors come from? Evolution!
Evolutionary Neurobiology Lab

- Incorporated numerous toxins and toxicants to study organism’s response
- Nicotine and withdrawal in *Planaria*
- Alcohol in *Drosophila*
- Caffeine in mice

BOTTOM LINE: All can be directly tied back to at least 3 major themes and ultimately 4th level toxicology learning objectives
Neurosignaling Lab

- Focused heavily on student-driven experimental design, but…
- Search for *C. elegans* mutants (polymorphisms of susceptibility and resistance)
- Compared three species of *Planaria* (most sensitive species)
- Factors affecting the stress response (homeostasis)
- Impact of diet (environmental factors; co-exposures)

BOTTOM LINE: If you start with an evolutionary focus, you will almost always pull in 2-3 other major themes and respective 4th level objectives
Anatomy and Physiology

- Primarily geared toward health professions (pre-meds, nursing, etc.)
- Non-majors version (nursing) does not require first-year biology
- Both focus almost exclusively on human systems
- Both heavily emphasize homeostatic imbalances and lifespan differences
When in Doubt, Talk About Smoking

- Effects on lung physiology (lung function measured in lab)
- Effects on alveolar structure (microanatomy shows emphysema v. healthy lung)
- Chronic effects seen through tar buildup
- Carcinogenic effects seen in preserved tumors from cadavers

ADD: discussion of susceptibility genes

Level 1: Biological information
Level 2 Gene-environment interactions
Level 3: Polymorphisms affecting risk
Level 4: Allelic differences associated with cancer
And Then Talk About Drinking!

- Chronic drinking → changes in liver and smooth ER
- Polymorphisms in ALDH-2 → slower metabolism and toxic building
- Effects on nervous system
- Co-exposure with acetaminophen

Level 1: Biological information
Level 4: Allelic differences associated with ethanol metabolism

Level 1: Evolution
Level 4: List common methods of detoxification

Level 1: Risk management
Level 4: Medical care for victim of poisoning
Summary

- You don’t have to teach a toxicology course to teach toxicology.
- Evolution is a cornerstone concept for all biology courses.
- Laboratory courses can demonstrate model organisms, systems biology, gene-environment interactions, dose-response, etc.
- Human health focused courses provide ample opportunity to incorporate toxicology case studies.
Questions and Comments

● Please participate.
● Send to “All Panelists” via the Q&A panel in the lower right.
SOT Undergraduate Toxicology Curriculum Resources

The Society of Toxicology supports the teaching of toxicology to undergraduates and has an active community of undergraduate educators. The Education Committee Undergraduate Subcommittee encourages any SOT member interested in undergraduate instruction to join this Undergraduate Educator Network by subscribing to ToXchange.

Undergraduate Education Network Newsletter September 2019

Activities related to undergraduates at the SOT Annual Meeting are featured in this flyer, which you can distribute, print, and post.

We encourage poster abstract submissions for the education, ethical, legal, and social issues topic poster session. More information

This resources below are available for teaching toxicology. Integrating the discipline into other courses, and for outreach activities.

www.toxicology.org/education/edu/resources.asp
Undergraduate Educator Network Webinars

- Don’t Sweat It…Three Dry Labs for Undergraduate Toxicology Programs (January 11, 2018)
- Using Non-Vertebrate Model Organisms to Illustrate Toxicology Principles in Undergraduate Lab Classes (October 20, 2016)
- Using Fish to Illustrate Toxicology Principles in Undergraduate Lab Classes (December 15, 2015)

...and six more

www.toxicology.org/education/edu/ugWebinars.asp
Undergraduate Educator Network Webinars

Thank you for participating today!

Please provide feedback via the link sent by email.