University of Pittsburgh

Kenneth P. Dietrich School of Arts and Sciences
Department of Chemistry

A Teaching Innovation at Chemistry

Engaging students in interdisciplinary research in chemistry laboratory course to discover new antibiotics

Lingfeng Liu, Joseph J Grabowski, Kay M Brummond
Course Description

Department of Biological Sciences  Antibiotics Discovery  Department of Chemistry

Small World Initiative (1 credit)  Honors Organic Chemistry Lab (2 credits)

Strains discovery  Antibiotics Discovery

Control Strain: Lysobactor Antibioticus  Unknown Strain
Antibiotic Crisis Statistics

2,049,442 illnesses, 23,000 estimated deaths per year nationally as a result of antibiotic resistance - (CDC).

If no action is taken between now and 2050, the true cost of antimicrobial resistance is estimated to be $100 trillion and 300 million premature deaths - (WHO)

MRSA kills more Americans each year than HIV/AIDS, Parkinson’s disease, emphysema, and homicide combined - (NIH)

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Goals and Rationales

• Create an innovative curriculum to integrate frontier discovery-based scientific research with undergraduate laboratory courses.

• Promote cross-department efforts to integrate curriculum and offer an interdisciplinary research experience for students.

• Form an undergraduate workforce from prominent research projects.

• Foster creative research mentor and teacher training for graduate students.

• Enhance and diversify the chemistry curriculum to attract more high quality students to Pitt.
Laboratory Dynamics Led by Students

- Global Project Planning
  - Experimental Design
  - Discussion/Peers Feedback
    - Bench Experiments
    - Data Analysis
  - Capstone Poster Presentation
Strategies for Antibiotics Discovery

Initial Investigations and Purification Procedures

1. Incubation of Bacteria and Liquid-Liquid Extraction
   - L. antibioticus grown in NB broth, and extracted with ethyl acetate

2. Thin-Layer Chromatography
   - Used to quickly observe how many compounds in crude sample

3. Reverse-phase column chromatography and disc assay
   - Separation of compounds by polarity, eluting from most non-polar to most polar

4. Normal-phase column chromatography and disc assay
   - Separation of the individual compounds present in the active fraction and detection of UV spectra

5. High Performance Liquid Chromatography

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Characterization Procedures and Strategies

**Mass Spectrometry**
Determines the molar mass of the compound and possible molecular formulas

**Infrared Spectroscopy**
Determines various identities of functional groups in a molecule

**1H NMR**
Determines the physical and chemical properties of the hydrogen atoms in a molecule

**Carbon-13 NMR**
Determines the physical and chemical properties of the carbon atoms in a molecule

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Course Transformation: Honors Organic Chemistry Lab vs Organic Chemistry Lab

• Authentic research on a real-world problem
• One central research project
• All techniques are centered around the research project
• Techniques are used in modern day research
• Students lead the research

• Experiments on known projects
• Each lab session is an independent experiment
• 1-3 techniques per lab
• Techniques are traditional
• Research is pre-designed for students
Enrollment of the antibiotics discovery course

## Antibiotics Discovery Lab

<table>
<thead>
<tr>
<th>Term</th>
<th>Course #</th>
<th>Offered</th>
<th>Enrolled</th>
<th>Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2015 (2161)</td>
<td>0330, 1c</td>
<td>2 x 8</td>
<td>16 (16c)</td>
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<tr>
<td>Spring 2016 (2164)</td>
<td>0750, 1c</td>
<td>2 x 8</td>
<td>16 (16c)</td>
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<tr>
<td>Fall 2016 (2171)</td>
<td>0750, 2c</td>
<td>2 x 12</td>
<td>24 (48c)</td>
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<tr>
<td>Spring 2017 (2174)</td>
<td>0750, 2c</td>
<td>3 x 12</td>
<td>30 (60c)</td>
<td>306</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(2c lab meets for two 4-hr sessions per week)</td>
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<tr>
<td>Fall 2017 (2181)</td>
<td>0745, 2c</td>
<td>3 x 12*</td>
<td>36 (72c)</td>
<td>306</td>
</tr>
<tr>
<td>Spring 2018 (2184)</td>
<td>0745, 2c</td>
<td>3 x 12#</td>
<td>36 (72c)</td>
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Statistics of the Students in the Antibiotics Discovery Course

2171, 2 sections
Antibiotics Discovery

<table>
<thead>
<tr>
<th>School</th>
<th>22 ---DSA&amp;S</th>
<th>2 ---SSoE</th>
<th>0 ---CGS</th>
<th>0 ---CBA</th>
<th>24 ---Sum</th>
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<tbody>
<tr>
<td>Academic Standing</td>
<td>0 ---Freshman</td>
<td>33 ---Sophomore</td>
<td>14 ---Junior</td>
<td>7 ---Senior</td>
<td>24 ---Sum</td>
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</table>

<table>
<thead>
<tr>
<th>Just Antibiotics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthropology</td>
</tr>
<tr>
<td>Biological Sciences</td>
</tr>
<tr>
<td>ChE</td>
</tr>
<tr>
<td>Chemistry</td>
</tr>
<tr>
<td>Bioinformatics</td>
</tr>
<tr>
<td>Microbiology</td>
</tr>
<tr>
<td>Molecular Biology</td>
</tr>
<tr>
<td>Neuroscience</td>
</tr>
<tr>
<td>Undeclared</td>
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<tr>
<td>Sum→</td>
</tr>
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</table>

Source: OrgoEnrollments.xlsx (27 Feb 2017, JJG)
Statistics of the Students in the Antibiotics Discovery Course

2174, 4 sections; 1 Synthesis; 3 Antibiotics Discovery

<table>
<thead>
<tr>
<th>School</th>
<th>Academic Standing</th>
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<tbody>
<tr>
<td>43</td>
<td>DSA&amp;S</td>
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<tr>
<td>3</td>
<td>SSoE</td>
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<tr>
<td>1</td>
<td>CGS</td>
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<tr>
<td>1</td>
<td>CBA</td>
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<td>48</td>
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<table>
<thead>
<tr>
<th>All</th>
<th>Major</th>
<th>Just Antibiotics</th>
<th>Just Synthesis</th>
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<tr>
<td>1</td>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Biological Science</td>
<td>5</td>
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<tr>
<td>3</td>
<td>ChE</td>
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<td>3</td>
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<tr>
<td>6</td>
<td>Chemistry</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>English</td>
<td>1</td>
<td>1</td>
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<tr>
<td>1</td>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Microbiology</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Molecular Biology</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>Natural Sciences</td>
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<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Neuroscience</td>
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<td>11</td>
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</tr>
<tr>
<td>48</td>
<td>--Sum--&gt;</td>
<td>30</td>
<td>18</td>
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Course Survey: Project Ownership

Article

The Project Ownership Survey: Measuring Differences in Scientific Inquiry Experiences

David I. Hanauer*; † and Erin L. Dolan‡

*Indiana University of Pennsylvania, Indiana, PA 15705; †PHIRE Program, Hartfull Laboratory, University of Pittsburgh, University of Pittsburgh, Pittsburgh, PA 15260; ‡Department of Biochemistry and Molecular Biology, University of Georgia, Athens, GA 30602

Project Ownership is one of the psychosocial factors involved in student retention in science. This survey measures project ownership content and emotion.
The Laboratory Course Assessment Survey: A Tool to Measure Three Dimensions of Research-Course Design

Lisa A. Corwin,* Christopher Runyon,† Aspen Robinson,‡ and Erin L. Dolan*

*Texas Institute for Discovery Education in Science, College of Natural Sciences, and †Department of Educational Psychology, University of Texas at Austin, Austin, TX 78712; ‡Department of Psychology, University of North Carolina at Charlotte, Charlotte, NC 28223

The Laboratory Course Assessment Survey measures student’s perception of three design features of the lab course: 1. collaboration; 2. discovery and relevance; 3. iteration.
Course Survey: Fall 2016

<table>
<thead>
<tr>
<th>Course</th>
<th>Total Scanned</th>
<th>Valid (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 0750</td>
<td>24</td>
<td>100</td>
</tr>
<tr>
<td>CHEM 0345</td>
<td>301</td>
<td>84.4</td>
</tr>
<tr>
<td>CHEM 0340</td>
<td>82</td>
<td>86.6</td>
</tr>
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</table>
1. My research will help to solve a problem in the world.

2. My findings were important to the scientific community.
3. I faced challenges that I managed to overcome in completing my research project.

4. I was responsible for the outcomes of my research.

5. The findings of my research project gave me a sense of personal achievement.

6. I had a personal reason for choosing the research project I worked on.
7. The research question I worked on was important to me.

8. In conducting my research project, I actively sought advice and assistance.

9. My research project was interesting.

10. My research project was exciting.
12. To what extent does the word **delighted** describe your experience of the laboratory course?

13. **happy**
18. I was encouraged to discuss elements of my investigation with classmates or instructors.

19. I was encouraged to reflect on what I was learning.
20. I was encouraged to contribute my ideas and suggestions during class discussions.

21. I was encouraged to help other students collect or analyze data.

22. I was encouraged to provide constructive criticism to classmates and challenge each other’s interpretations.

23. I was encouraged to share the problems I encountered during my investigation and seek input on how to address them.
Laboratory Course Assessment
Survey_Discovery & Relevance

24. I was expected to generate novel results that are unknown to the instructor and that could be of interest to the broader scientific community or others outside of class.

25. I was expected to conduct an investigation to find something previously unknown to myself, other students, and the instructor.

<table>
<thead>
<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Dis-agree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
</tr>
</tbody>
</table>

![Bar chart for question 24](chart_24)

![Bar chart for question 25](chart_25)
26. I was expected to formulate my own research questions or hypothesis to guide an investigation.

27. I was expected to develop new arguments based on data.

28. I was expected to explain how my work has resulted in new scientific knowledge.
Laboratory Course Assessment
Survey_Iteration

29. I was expected to revise or repeat work to account for errors or fix problems.

30. I had time to change the methods of the investigation if it was not unfolding as predicted.
31. I had time to share and compare data with other students.

32. I had time to collect and analyze additional data to address new questions or further test hypotheses that arose during the investigation.

33. I had time to revise or repeat analyses based on feedback.

34. I had time to revise drafts of papers or presentations about my investigation based on feedback.
A Measure of College Student Persistence in the Sciences (PITS)

David I. Hanauer, Mark J. Graham, and Graham F. Hatfull
Department of English, Indiana University of Pennsylvania, Indiana, PA 15705; Yale Center for Teaching and Learning, Yale University, New Haven, CT 06510; Department of Biological Sciences, University of Pittsburgh, Pittsburgh, PA 15260

FIGURE 1. Model of the psychological outcomes of CREs leading to the intention to stay in the sciences.
Acknowledgements

Department of Biological Sciences
Jean Schmidt
Elia Crisucci
Nancy Kaufmann
Jessica Robertson

Department of Chemistry
Joe Grabowski
Kay Brummond
George Bandik
Ericka Huston

Funding support:
Department of Chemistry

Spectroscopy Society of Pittsburgh
Scientists Promoting Education in Science for Over 50 Years

Society for Analytical Chemists of Pittsburgh
Our Research Journey: Adventures & Discoveries!