Authentic Research Experiences in Laboratory Courses

REIL-Biology Network

Nitya Jacob, Gary Reiness, Elisabeth Schussler, Rachelle Spell

non-presenting coauthors: Barbara Abraham, Larry Blumer, Chris Beck, Sibdas Ghosh, Judy Guinan, Lonnie Guralnick, Pamela Hanson, Nitya Jacob, Mary Miller, Kristen Miller, Craig Ogilvie, Gary Patterson, Joanna Vondrasek, Jen Rhode Ward, Larry Wimmers, Kathy Winnet-Murray

IBP Summer Conference
July 1, 2012

Supported by the National Science Foundation, RCN-UBE 1061798
Objectives of Interactive Session

1. Describe advantages of Authentic Research Experiences in biology laboratory courses
2. Discuss definitions of authentic research
3. Discuss barriers and catalysts to implementation
4. Present successful implementation examples by REIL-Biology network members
5. Solicit examples of implementation from the audience
VISION AND CHANGE IN UNDERGRADUATE BIOLOGY EDUCATION: A CALL TO ACTION

PREFACE

“Appreciating the scientific process can be even more important than knowing scientific facts. People often encounter claims that something is scientifically known. If they understand how science generates and assesses evidence bearing on these claims, they possess analytical methods and critical thinking skills that are relevant to a wide variety of facts and concepts and can be used in a wide variety of contexts.”

—National Science Foundation, Science and Technology Indicators, 2008

www.visionandchange.org
Cultivating Biological Literacy

Action Items

Introduce research experiences as an integral component of biology education for all students, regardless of their major.
“Results from the SURE survey ... indicate that even a short immersion experience is sufficient to effect long-term gains in student motivation for learning, independence and understanding of science (Lopatto, 2007).”
Vision and Change –
Integrating Undergraduate Research Experiences

“Undergraduate participation in some kind of research in introductory courses, therefore, may be the key to developing an enduring understanding of core concepts for all undergraduate students.”
**REIL Biology**
*(Research Experience in Introductory Laboratories in Biology)*

- **Funding:** National Science Foundation Research Coordination Network for Undergraduate Biology Education Incubator Grant (NSF RCN-UBE)
- **Goal:** Increase authentic research experiences in introductory biology laboratory courses
REIL Biology Members

• in conjunction with
  – Association for Biology Laboratory Education (ABLE)
  – Council on Undergraduate Research (CUR)
  – and invitees
REIL Biology Goals

1. Survey on authentic research in introductory biology laboratories
2. Disseminate findings
3. Develop a full RCN-UBE proposal
   a. best practices and examples
   b. overcoming barriers
Special Mention

1. Writing the Survey – all of Core REIL-Biology
2. Quantitative Analysis – Chris Beck, Judy Guinan
3. Qualitative Analysis – Kris Miller, Chris Beck, Rachelle Spell
Survey of Research in Intro Labs

• 279 respondents
• 532 courses
• diverse institutions
  – 17% (48 of 279) 2-year colleges
  – 41% (114 of 279) liberal-arts colleges
  – 13% (39 of 279) comprehensive universities
  – 20% (57 of 279) research universities.
• diverse student body
  – 14% (39 of 279) minority-serving institutions
Demographic breakdown

Number of Institutions

Private

Public
Demographic breakdown

Number of Institutions

- 2-year college
- Liberal Arts College
- Comprehensive University
- Research University
Demographic breakdown

- Non-minority: 216 institutions
- Other minority-serving: 15 institutions
- Hispanic-serving Institution: 14 institutions
- HBCU: 8 institutions
- Tribal: 2 institutions
Course breakdown

- **Number of courses**
  - **non-majors**
  - **majors**
  - **mixed**
  - **pre-health**
  - **other**

- **Research University**
- **Comprehensive University**
- **Liberal Arts College**
- **2-year college**
Defining Authentic Research
Defining Authentic Research Reflections

• Key terms?
20 Most Common Words in Definitions of Authentic Research

- data
- design
- develops
- experiment
- experimental
- hypothesis
- methods
- observations
- presentation
- project
- question
- research
- results
- scientific
- testing
- working
Themes based on common words in definitions of authentic research

- Novel Questions (i.e., unknown results)
- Student-generated Questions
- Hypothesis Formation
- Experimental Design
- Data Analysis
- Presentation or Publication
Definitions of Authentic Research preliminary quantification
Factors influencing definitions of authentic research

• 2-year college faculty \textit{less} likely to include Experimental Design
• ABLE members much \textit{more} likely to include Experimental Design
• CUR members much \textit{more} likely to include Novel Questions
• NABT members \textit{less} likely to include Hypothesis Formation and Presentations and Publications (marginally significant given number of tests)
Conclusions of definitions

• no one clear definition
• can incorporate several components
• therefore, must support many models of incorporation of research into the curriculum
Implementing Authentic Research
Research in intro lab courses
Effect of course type on research
Effect of institution type on research

![Box plot showing the effect of institution type on research](image)

- 2-year
- Liberal arts
- Comprehensive
- Research

Institution Type

% research
Effect of institution type on research

P=0.001

N.S.
Barriers to Authentic Research

- Cost
- Lack of instructor preparation
- Instructor resistance
- Lack of lab prep support
- Lack of facilities
- Lack of equipment
- Effects on student evaluation of instructors
- Loss of content coverage and breadth
- Additional workload
- Lack of time for faculty to develop new research experiences
- Lack of ways to effectively assess students
- Class size
- Number of sections
- Lack of student preparation
Conclusions of Barriers

TIME
Not significant barriers, generally

- class size
- section numbers
- facilities
Effect of Institution Type on Barriers: Lack of Equipment

![Box plot showing effect of institution type on barriers: Lack of Equipment.](image)
Effect of Institution Type on Barriers: Class Size

- 2-year
- Liberal arts
- Comprehensive
- Research
Effect of Institution Type on Barriers: Student Preparation

![Box plot showing the effect of institution type on barriers to student preparation]
Barriers to Authentic Research at Minority-serving Institutions

• Lack of administrator support
• Lack of facilities
• Lack of time for faculty to develop new research experiences
• Effects on student evaluation of instructors
Barriers to Authentic Research at Public Institutions

- Cost
- Lack of equipment
- Lack of student preparation
- Effects on student evaluation of instructors
List of Network Member Modules of Research in the Curriculum

by institution type
## 2 Year College

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Course</th>
<th>Module</th>
<th>Type of course-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitya Jacob</td>
<td>Oxford College (liberal arts intensive 2 year college)</td>
<td>Intro Bio for majors</td>
<td>Arabia Mountain</td>
<td>Student-generated question and hypothesis, guided inquiry</td>
</tr>
<tr>
<td>Joanna Vondrasek</td>
<td>Piedmont Virginia Community College community college</td>
<td>Required research course for science majors</td>
<td>Semester-long independent research</td>
<td>Student-generated question</td>
</tr>
<tr>
<td>Joanna Vondrasek</td>
<td>Piedmont Virginia Community College community college</td>
<td>Non-majors biology</td>
<td>bean beetle labs</td>
<td>Semester-long, guided inquiry</td>
</tr>
<tr>
<td>Joanna Vondrasek</td>
<td>Piedmont Virginia Community College community college</td>
<td>sophomore level Cell Bio and Genetics courses</td>
<td>fairly open-ended multi-week labs</td>
<td></td>
</tr>
<tr>
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<tr>
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<td>-----------------</td>
</tr>
<tr>
<td>Lawrence Blumer</td>
<td>Morehouse College (private liberal arts, HBCU)</td>
<td>Freshman Course</td>
<td>HHMI Phage Hunters</td>
<td>Novel question</td>
</tr>
<tr>
<td>Lawrence Blumer</td>
<td>Morehouse College (private liberal arts, HBCU)</td>
<td>majors introductory laboratory</td>
<td>bean beetle guided-inquiry</td>
<td>Student-generated questions and expt design?</td>
</tr>
</tbody>
</table>
## Liberal Arts

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<tbody>
<tr>
<td>Sibdas Ghosh</td>
<td>Dominican University of California (liberal arts college)</td>
<td>Undergraduate Research Sequence, starting 2nd semester</td>
<td></td>
<td>Research methodology</td>
</tr>
<tr>
<td>Lonnie Guralnick</td>
<td>Roger Williams University (public college)</td>
<td>Intro Bio lab at Western Oregon</td>
<td>Ecology module for majors intro</td>
<td>Directed inquiry, term-long project</td>
</tr>
<tr>
<td>Pam Hanson</td>
<td>Birmingham-Southern College (liberal arts college)</td>
<td>Upper level genetics course and intro honors cell and molecular biology,</td>
<td>KP1019</td>
<td>Semester long novel research project</td>
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## Liberal Arts

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<tbody>
<tr>
<td>Mary Miller</td>
<td>Rhodes College (liberal arts college)</td>
<td>Intro Bio Sequence</td>
<td>Student-designed experiment, focus on scientific communication</td>
<td></td>
</tr>
<tr>
<td>Jen Rhode Ward</td>
<td>UNC-Asheville (public liberal arts college, with ~250 majors)</td>
<td>Freshman and sophomore courses</td>
<td>Plant ecology, physiology, and genetics</td>
<td>authentic research-based lab work</td>
</tr>
<tr>
<td>Kathy Winnett-Murray</td>
<td>Hope College (liberal arts college)</td>
<td>non-majors</td>
<td>investigation of the impacts of invasive plant species in ecological communities</td>
<td>month-long group research project, jigsaw approach</td>
</tr>
</tbody>
</table>
## Comprehensive Universities

<table>
<thead>
<tr>
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<th>Institution</th>
<th>Course</th>
<th>Module</th>
<th>Type of course-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barbara J Abraham</td>
<td>Hampton University (HBCU)</td>
<td>majors Intro Bio</td>
<td>Analyses of chemistry and animals in soil samples</td>
<td>3-4 week module with student-generated question, presentation and paper</td>
</tr>
<tr>
<td>Judy Guinan</td>
<td>Radford University</td>
<td>Introductory majors</td>
<td></td>
<td>Guided inquiry, then student-designed question and experimental design, analysis and presentation</td>
</tr>
<tr>
<td>Larry Wimmers</td>
<td>Towson University</td>
<td>Intro labs</td>
<td></td>
<td>guided inquiry with student generated hypothesis and design</td>
</tr>
</tbody>
</table>
# Research Universities

<table>
<thead>
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<th>Course</th>
<th>Module</th>
<th>Type of course-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kristen Miller</td>
<td>UGA (public university)</td>
<td>Introductory Biology for majors, for majors</td>
<td></td>
<td>Student-designed experiments,</td>
</tr>
<tr>
<td>Craig Ogilvie</td>
<td>Iowa State University</td>
<td>Multiple courses, approximately 1000 students per year courses</td>
<td>5-6 week research projects in 9 science lab courses</td>
<td>learning communities of faculty and graduate student TAs</td>
</tr>
<tr>
<td>Elisabeth Schussler</td>
<td>University of Tennessee (public university)</td>
<td>Second semester introductory biology for majors (cell biology)</td>
<td>Four 2-week guided laboratories</td>
<td>Guided inquiry based on research by UT faculty members</td>
</tr>
<tr>
<td>Rachelle Spell</td>
<td>Emory University (research university)</td>
<td>Research Methods Course</td>
<td>Semester-long novel research</td>
<td>Entry level (freshman and up)</td>
</tr>
</tbody>
</table>
Example Module: Investigating Arabia Mountain: A Molecular Approach

Introductory Biology Laboratory
by Nitya Jacob
Oxford College
1) Literature Research – Proposal
   “Thinking Time”
   (Student ownership)

2) Sample collection

3) Laboratory bench work

4) Data analysis
   “Thinking Time”
   (Student ownership)

Connection to Biology 141

5) Communicating Evidence

Investigating Arabia Mountain: A Molecular Approach

(Student ownership)
Building the foundation of a research-rich curriculum

Gary Reiness

Department of Biology, Lewis & Clark College, Portland, OR
We want our graduates to:

• understand the process of scientific inquiry
• be independent learners
• recognize that ‘facts’ are hypotheses well-supported by evidence
• be able to draw appropriate conclusions from experimental data
• understand what kinds of issues are amenable to scientific inquiry and what kinds are not
• be able to collaborate effectively

Like many of you, we try to achieve those goals by emphasizing student-designed, inquiry-driven laboratories
Use lecture time to teach experimental design and data analysis

**Experimental Design**

Two options

- **Manipulative**: where the investigator actually does something to the system and measures the effects of these manipulations on variables of interest.
- **Correlational**: makes use of natural variation to look for the effect of one factor on another.

**Correlational approach**

See which bird gets the most mates during the breeding season.

**Manipulative approach**

- **Group 1**: Shortest feathers
- **Group 2**: Extended feathers
- **Group 3**: Manipulation control

Manipulate tail length, band birds, and monitor the number of matings.

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**Bird Tail Feather Example**

**Hypothesis:**

Long tail feathers seen in many species of birds have evolved to make males more attractive to females.
Introduce Primary Literature

- Even first semester students can read carefully chosen papers
- Class discussions are used to develop ability to critically evaluate experiments
- Students develop “taste” from comparing good and flawed work
- Good experiments provide models for students designing their own
Provide feedback on projects prior to execution

- Student groups present research proposals to peers
- Proposals are critiqued by peers and course staff
- Students receive feedback on their experimental plan, and
- Learn from the strengths and weaknesses of other proposals
Monitor progress of experiments

- Obtain regular reports on progress of experiments (or make site visits to field studies)
- Helps students stay on task and assists in troubleshooting or modifying experiment
- Helps reduce last-minute scrambles for data or failed studies
Assign written reports to be drafted in stages, with revision

- For multi-week projects, students write Introduction and Methods before obtaining Results.
- Instructor critiques these and students revise them
- Student groups outline Introduction, Results, and Discussion sections in lab (with instructor feedback) to assure common understanding, enrich collaborative interpretation, and reduce “you write section A and I’ll write B” discontinuities.
Assign oral presentations of results, with emphasis on “research lessons learned”

• Students must describe what they would do differently if repeating their experiment
• The lab manual provides a grading rubric

These are the criteria by which your group's oral report will be graded. When you rehearse it, make sure that you can answer "yes" to each of the following questions.

CHECKLIST FOR ORAL REPORTS

_____ Was the question or hypothesis clearly described, early in the presentation? Was it clear why the group thought this was an interesting question, what they expected to see, and why?

_____ Was the design of the study clearly described?

_____ Were the study's results presented in a way that was easy to understand? Were important trends described? Were visual aids used when appropriate? Were they clear and well explained?

_____ Were the conclusions described and explained/justified?

_____ Did the presentation include a description of what the group would do differently if they repeated the study, and why?

_____ Did all members of the group contribute to the presentation? Was the presentation vivid and interesting, which effectively communicated the major findings?
Infusing faculty research into an introductory biology laboratory

Elisabeth Schussler, University of Tennessee, Division of Biology

Course: Organization and Function of the Cell
Second semester majors’ course
>900 students per academic year

Previous lab: cookbook, techniques

In 2011, identified research of four UTK faculty members to be the basis of new guided inquiry laboratories
Infusing faculty research into an introductory biology laboratory

Elisabeth Schussler, University of Tennessee, Division of Biology

Each lab,
Week 1: background and techniques, collect and analyze preliminary data, brainstorm hypothesis and experimental design for another experiment given supplies available

Week 2: collect data, analyze data, compile and present an oral communication

Follow-up: Written lab communication

End of semester: Group presentation on how they would continue experimentation on one of the systems they worked with that semester
Example Module:
Novel Research Lab Course

Bio285 Biology Laboratory

Rachelle Spell

Emory University
Biol285 Research Course

Collaboration with Pamela Hansen (Birmingham-Southern College) and Mary Miller (Rhodes College)

• novel question: effect of a new metallo-compound chemotherapy agent KP1019 on yeast
• given experimental design
• scientific communication: paper and poster presentation
• designed for freshman
Breakout

Please share

• factors that contribute/d to your success
• barriers that limit/ed your success
• interest in joining our network
Next Steps for REIL-Biology

• disseminate findings
  – presentations
  – publications

• submit full grant proposal
  – identify best practices
  – recruit more network members
  – gather real-life examples
  – address barriers to increase implementation
Thank you

Please join our network activities