An Integrated & Inquiry-based Approach to Exploring Plant Metabolism
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This presentation will be available at my website: http://petersj.people.cofc.edu/CCLI/

<table>
<thead>
<tr>
<th>Guided verification-style lab</th>
<th>Inquiry-based lab</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What was the initial context for the lab?</strong></td>
<td>Concepts/processes initially discussed in lecture</td>
</tr>
<tr>
<td><strong>How was knowledge required to perform the lab acquired by students?</strong></td>
<td>Class or pre-lab lecture or assigned textbook chapter</td>
</tr>
<tr>
<td><strong>What was source of experimental question, hypothesis, methods and predictions?</strong></td>
<td>Explicitly provided by the lab manual or instructor</td>
</tr>
<tr>
<td><strong>What support was provided to help students explain their findings?</strong></td>
<td>The lab manual or instructor provided specific conceptual questions to answer.</td>
</tr>
<tr>
<td><strong>How did students communicate findings?</strong></td>
<td>Lab report with specific questions to answer or topics to address.</td>
</tr>
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Pedagogical structure of labs...

An observation, question, topic, or case study that contextualizes the lab exploration, engages the learner and elicits wonder & reflection.

Reveal current conceptions
What do we know (or think we know)?
Framing the problem or question
What do we need to know?
Organize and connect knowledge from background research.
Readings, interactive tutorials and homework activities

Engage, Connect & Wonder

Explore, Frame & Question

Conduct, Analyze & Explain

Research & Formulate hypotheses, experimental predictions

Draft conclusions.

Feedback to Build Deeper Understanding
Peer-evaluation & instructor feedback, and opportunities to revise work & thinking.

Authentic Evaluative Assignments which:
• Connect lab finding to science-related issues!
• Foster communication of science BOTH to scientists and to the public.

Lab curricular structure

<table>
<thead>
<tr>
<th>Stage of Inquiry</th>
<th>Traditional Verification</th>
<th>Guided-Inquiry (Practicing inquiry)</th>
<th>Student-directed (Performing inquiry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context for Inquiry</td>
<td>Concepts or processes covered in lecture or textbook</td>
<td>Student observations of nature or a relevant problem or case study.</td>
<td></td>
</tr>
<tr>
<td>Background research</td>
<td>Initial content lecture or reading provided to students</td>
<td>Assigned reading supplemented with independent research.</td>
<td>Independently decide the background knowledge required, and learning resources to use.</td>
</tr>
<tr>
<td>Scientific question</td>
<td>Question provided by teacher</td>
<td>Generate questions with some guidance</td>
<td>Students pose their own questions.</td>
</tr>
<tr>
<td>Methods</td>
<td>Experimental methods and analysis procedures are provided</td>
<td>Make some methodological and analysis decisions with guidance</td>
<td>Independently decide on methods and analysis procedures.</td>
</tr>
<tr>
<td>Explanations</td>
<td>Provided questions to answer about the findings</td>
<td>Students are provided general guidelines on what to discuss in their explanations</td>
<td>Students independently formulate their own explanations.</td>
</tr>
<tr>
<td>Connections to concepts</td>
<td>Students explicitly told which concepts to use through specific questions</td>
<td>Coached to make certain concept connections through independent research</td>
<td>Independently decided in student research teams.</td>
</tr>
<tr>
<td>Communication of findings</td>
<td>Answering lab follow-up questions</td>
<td>Written discussion of findings with guidance from lab or instructor coaching.</td>
<td>Independently. Multiple forms of communication or media used. Peer review is stressed.</td>
</tr>
</tbody>
</table>
Independent Research Projects

- Multi-week and in-depth exploration
- Student-directed:
  - Student observations, experiences and interests set the context for the project.
  - Students
    - formulate questions, hypotheses, experimental predictions.
    - design procedures
    - summarize and analyze quantitative data
    - draw conclusions
    - authentically communicate findings
    - work collaboratively and independently
  - Model how the scientific community works to strengthen studies and validate knowledge.

Today’s lab...

Authentic Evaluative Assignments & Ongoing Feedback
- Each student writes a draft scientific article.
- Draft articles are peer-reviewed by another team and by the lab instructor.
- Teams present their work at an end of term scientific symposium.
- Quality articles are posted on JUBI

Students observe variations in plant morphology, development, genetics or environmental conditions; develop a question, pose a hypothesis and identify what they need to know more about to inform their proposal.

Student observations of & connections between various facets of plant metabolism

Experiment, collect, summarize & analyze data; Research to inform conclusions. Draft conclusions.

Student teams develop a scientific research proposal, and evaluate another team’s proposal.
Why should we teach labs this way?

Action Items from Vision & Change

- Introduce the scientific process to students early, and integrate it into all undergraduate biology courses.
- Define learning goals so that they focus on teaching students the core concepts, and align assessments so that they assess the students’ understanding of these concepts.
- Relate abstract concepts in biology to real-world examples on a regular basis, and make biology content relevant by presenting problems in a real-life context.
- Develop lifelong science learning competencies.
- Introduce fewer concepts, but present them in greater depth.
- Stimulate the curiosity students have for learning about the natural world.
- Demonstrate both the passion scientists have for their discipline and their delight in sharing their understanding of the world with students.

Vision & Change in Undergraduate Biology Education: A Call to Action

Core Competencies

APPLY THE PROCESS OF SCIENCE:
Biology is evidence based and grounded in the formal practices of observation, experimentation, and hypothesis testing.

USE QUANTITATIVE REASONING:
Biology relies on applications of quantitative analysis and mathematical reasoning.

USE MODELING AND SIMULATION:
Biology focuses on the study of complex systems.

TAP IN TO THE INTERDISCIPLINARY NATURE OF SCIENCE:
Biology is an interdisciplinary science.

COMMUNICATE AND COLLABORATE WITH OTHER DISCIPLINES:
Biology is a collaborative scientific discipline.

UNDERSTAND THE RELATIONSHIP BETWEEN SCIENCE AND SOCIETY:
Biology is conducted in a societal context.
Fostering a “Spirit of Inquiry”!

Exploring Plant Metabolism

Ahoy!!...there are some mitochondria in there!

What unintended messages does this figure send to students about the relations between cellular respiration and photosynthesis in nature?
Vernier CO₂ Sensors...

1. Plug the sensor into one of the channel ports on the LabQuest2 data logger.
2. Turn on the data logger.
3. Wait at least one minute for the sensor to warm up.
4. If the sensor is reading below 200 ppm or above 600 ppm, then it needs calibration.
5. Use the LabQuest2 stylus to push the CAL button once.

1. Download the Vernier GoDirect sensor app *Graphical Analysis 4* from the app store.
2. Push the button to turn on the sensor.
3. Blinking red light means the sensor is ready to connect.
4. Open the Graphical Analysis 4 app and pair the sensor via proximity or enter the sensor ID number, which is above the barcode on the back of the sensor.

Fostering Effective Collaboration

**Team Work**
- Develop questions & initial hypotheses
- Develop proposal
- Proposal Peer-review
- Revise & conduct experiment, summarize and analyze data
- Share research and formulate general conclusions
- Research Symposium

**Individual Work**
- Background research to inform hypotheses, protocols & predictions
- Research to explain findings
- Write article abstract, introduction & conclusion
- Peer Evaluation of Presentations & Publication

Effective team projects engender positive interdependence among team members while facilitating individual accountability for learning concepts and competencies.
Discovering Biological Science

- **Student Support Materials**
  - Team Lab Notebooks (TLNs)
  - Homework Activities
  - Interactive Tutorials
  - “Doing Science” Guides

- **Instructional Guides**
  - Conceptual and scientific skills goals
  - Materials & lab setup instructions
  - Pedagogical tips for facilitating student centered, inquiry-based & collaborative learning.
  - Assignment grading & feedback rubrics
  - Instructional PowerPoints
  - Ideas for connecting lab & class (coming soon)

For more information on the Discovering Biological Science labs...

Visit my website: [http://petersj.people.cofc.edu/CCLI/](http://petersj.people.cofc.edu/CCLI/)