

The Wisconsin Program for Scientific Teaching

Un-cooking the Lab

A Guide to Constructing Inquiry-based Labs in Biology

An inquiry-based lab asks students to address a challenge, solve a problem, test a hypothesis, explain a phenomenon, or answer a question in the same manner that a scientist approaches a research question. The goal of an inquiry-based lab is for students of all backgrounds to learn biology by experiencing the process of science and the thrill of first-hand discovery.

Features of an Inquiry-based Lab

The primary feature of an inquiry-based lab is that students experience science as an experimental process that uses evidence to explain natural phenomena. Students will:

1. Learn essential concepts, skills, and behaviors that reflect that nature of science.
2. Think analytically and critically about experimental design.
3. Take responsibility for their own learning in a way that is engaging and meaningful to them.
4. Experience the collaborative nature of science as they negotiate with peers and communicate their explanations.
5. Use evidence as the basis for their explanations of natural processes.
6. Witness the thrill of discovery and uncertainty of biology.

Examples of Approaches to Labs

| Inquiry-based Labs | NOT Inquiry-based Labs |
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| Students are asked to bring in two soil samples, are challenged to generate a hypothesis about the microbes in the soil samples, then design an experiment to test it. | Students are instructed how to make 10-fold dilutions of soil samples and apply each solution to a culture medium. After incubation, students count the number of colonies on each plate and calculate the number of culturable organisms in the sample. |
| Students are asked to generate a hypothesis about the effect of the environment on the life cycle of a plant and test it. | Students are told to plant seeds and fertilize with a dilution series of fertilizer, then measure the effect on plant height, number of leaves, and number of seeds. |
| Students are given an unhealthy plant and asked to determine the cause of its symptoms. | Students are given a protocol to inoculate a plant with a known pathogen. A week later, they identify the correct disease symptoms and re-isolate the pathogen. |
| Students are given two seed stocks: one parent and its progeny. Students are challenged to generate a hypothesis about the second parent's genotype and design an experiment to test it. | Students are instructed to cross two true-breeding lines of fruit flies, then identify the correct genotype and phenotype of the progeny. |
| Students choose a single organism (bacterium or fungus) and are charged with its care for a semester. At the end of the project, they are responsible for returning a pure culture of the microbe, describing its interactions with other organism, characterizing it, and identifying it. | Students are given 10 microorganisms plus a list of 20 diagnostic media and told to determine the correct identity of each microorganism. |

Inquiry-based Labs: Constructing a Framework

| Questions to Consider | Examples of Phrasing and Techniques |
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| <p>Set Learning Goals</p> <p>What should students know, understand, or be able to do at the end of the lab?</p> <p>What methods, materials, or skills will students need to use?</p> <p>What attitudes and experiences do you expect them to have?</p> | <p><i>Examples of learning goals</i></p> <p><i>Science content:</i></p> <ul style="list-style-type: none"> • “DNA is the hereditary material for all life.” • “Specific microbes cause specific diseases in plants and animals.” <p><i>Experimental design:</i></p> <ul style="list-style-type: none"> • “Experiments provide a test for a hypothesis that observations alone cannot provide.” <p><i>Techniques:</i></p> <ul style="list-style-type: none"> • “Different sampling techniques detect different parts of a community.” • Let students know what materials are available. • Teach protocols on an as-needed basis. <p><i>Attitudes:</i></p> <ul style="list-style-type: none"> • “Students express interest in scientific research.” |
| <p>Represent the Nature of Science</p> <p>How do you expect students to approach the issue so they think critically and analytically about experimental design?</p> <p>How will the lab’s design foster collaboration and communication?</p> | <p><i>Example approaches that represent the nature of science</i></p> <ul style="list-style-type: none"> • “Design an experiment to test whether...” • “Design an experiment to test the effect of...” • “It is your job to determine how to characterize...” • “Propose a hypothesis about [a phenomenon] and design an experiment to test it.” <p><i>Example approaches to foster collaboration and communication</i></p> <ul style="list-style-type: none"> • “Work as groups to ___ then write individual reports in your own words.” • “Your group will present ___ to the class.” • “Together, decide on how you plan to ___ and justify why.” |
| <p>Engage Students in Learning</p> <p>What will be the “hook” for the lab that will engage students in learning so they take responsibility for their own learning?</p> | <ul style="list-style-type: none"> • Recent research finding • Historical discovery • Contrasting viewpoints • Newspaper article • Issue raised in the course |
| <p>Assess Regularly and Often</p> <p>How will you gauge the students’ understanding and encourage them to give priority to explanations based on evidence? How will <i>they</i> gauge their progress toward the learning goals?</p> <p><i>Before the lab:</i> What do the students already know (or think they know), and do what they need to know? What essential information/skills do they need <i>before</i> they begin?</p> <p><i>During the lab:</i> How will you know if they “get it?” What guiding questions will focus their discussions on experimental evidence?</p> <p><i>At the end of the lab:</i> How will you know if they have met the learning goals? Are students giving priority to evidence in their explanations?</p> | <p><i>Before the lab:</i></p> <ul style="list-style-type: none"> • Students answer brief questions about a textbook or web-based reading. • Students participate in an active learning exercise in lecture. • Students submit a paragraph online about their current attitudes toward the issue. • Students ask questions and brainstorm potential answers about the issue and information presented. <p><i>During the lab:</i></p> <ul style="list-style-type: none"> • Instructor asks guiding questions: “What’s your hypothesis?” “Tell me how your experiment tests it.” “Do you think the data explain ___?” • Student groups share hypotheses on board. • Entire class justifies what data to collect, and when and how to collect it. <p><i>At the end of the lab:</i></p> <ul style="list-style-type: none"> • Individual lab report • Group presentation • Grant proposal • Exam/quiz that applies knowledge and skills to a new scenario • Questions to assess attitudes about the experience and group collaboration |

Inquiry-based Labs: Flow of Activities in the Classroom

START

Prior knowledge

What do the students already know (or think they know)?

What essential information or skills do they need *before* they begin?

What misconceptions might they have about this topic?

Engagement

What is the “hook” that will engage students in learning?

DURING THE LAB

Inquiry challenge

What challenge will the students address?

The nature of science

How will the lab experience mirror scientific research and encourage students to use evidence as the basis for their explanations?

What methods, materials, or skills will students need to use?

What guiding questions will focus their discussions on experimental design and evidence?

END

Learning goals

What should students know, understand, and be able to do at the end of the lab?

How will you find out what students already know (or think they know) and what they need to know before they begin?

How will you determine whether students are using evidence as the basis for their explanations?

How will you know whether students have met the learning goals?

Scientific Teaching

Teaching goals

- Did the process go as you had planned?
- Do the assessments provide you with data about your teaching?
 - What worked well? What didn't? What evidence do you have?
 - What would you do differently next time, and why?
 - What new evidence would you like to gather next time?
- Do the learning goals of the lab reflect the nature of science?
 - Are students expected to base their explanations on evidence?
 - Are students expected to work collaboratively and build communications skills?
- Do the activities and assessments align with the learning goals?
- Does your teaching approach account for the diversity represented by your students?

Learning goals

- Did students meet the learning goals?
- Did students have the opportunity to gauge their progress toward the learning goals at multiple points during the lab?

References and Further Reading

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