DETAILED FACILITATION GUIDE

Engage

Introduce students to the phenomenon by presenting them with the images of water from lakes of differing water clarity. Ask students to make observations and ask questions about the images using the "I Notice, I Wonder" instructional strategy.

Discussion Support

As students share, record their ideas and elicit additional details or clarification using tools like Talk Science Resource Cards, which provide sentence and question stems for both students and teachers.

Student Answers and Teacher Response

- Students should point out the differences in water clarity, although they may describe this as some lakes being "dirtier" than others.
- Students may ask questions or make observations about the amounts of mud/dirt, leaves, trash, and pollutants that are in the water.
- If students don't mention algae or phytoplankton, you might guide them toward this idea or simply introduce it as a factor with the next set of images.

Continue engaging students in the phenomenon by presenting them with the images of the phytoplankton communities found in each of the four lakes, as seen under the microscope. Define phytoplankton (also called algae) as tiny plants that live in water. Explain the basic definition of water clarity as well. Direct students to look for patterns in the phytoplankton communities, adding these ideas and questions to the previous list.

Guide students to consider what might cause the amount of phytoplankton in the water to increase by asking them to list things that help plants grow.

Student Answers and Teacher Response

- Students should notice that both the amount and types of phytoplankton are different for each lake. They may also mention that the phytoplankton are different sizes and shapes and that some are single cells while others are made of multiple cells.
- Regarding things that help plants grow, students should mention light, water, carbon dioxide, and nutrients.
- Students may mention plant food or fertilizer instead of nutrients. If so, take this opportunity to introduce nutrients as building blocks to make more cells. The most common nutrients that plants need are nitrogen and phosphorus.

At this point, ask students to use the ideas from what they've observed and discussed so far to draw a model that explains the phenomenon.

Following the discussion, explain to students that in this lesson, they will focus on answering this question: "What factors explain how phytoplankton affect water clarity?" The question can be broken down into these two questions: "What factors cause phytoplankton to grow?" and "How do those factors indirectly affect water clarity?"

Formative Assessment

- Throughout the discussions, take note of what vocabulary students use and the assumptions they make.
- Listen for specific misconceptions, such as:
    - "individual phytoplankton rapidly adapt to different conditions" rather than dying,
    - "nutrients act as a source of energy" rather than building blocks, or
    - the idea that resources are limitless within the ecosystem.
- Use the preliminary models as a formative assessment, paying particular attention to:
    - the elements students include,
    - the cause-and-effect relationships described, and
    - whether students consider both environmental and genetic factors within their models.

Explore 1: Investigation

Note: *To keep all the investigation data collection and analysis information in one place, the "Phytoplankton Investigation" section comes after the "Roles in Phytoplankton Communities" section in the Student Notebook handouts (print pg. 8, digital pg. 7).*

Ask students to look at the factors they included in their models that they think affect phytoplankton growth. Based on this information, ask them how they can test one of their factors to see if their idea is correct. In pairs or small groups, students will plan and carry out an experiment, choosing a single variable to test that may affect phytoplankton growth. Make sure that more than one group is assigned to each variable (e.g., two groups test nitrogen, three groups test phosphorous, etc.) so they can later combine their data for analysis.

Make sure that some groups test increased nitrogen, increased phosphorus, or an addition of fertilizer that contains both nitrogen and phosphorus. If other students want to test light levels, pH, temperature, etc., consider adding these to the factors under investigation.

Students should record phytoplankton abundance data daily; the most efficient method for this is using a modified Secchi disk. For reference, this YouTube video demonstrates how to use a Secchi stick.

Secchi disks can be purchased online or you can make your own using the attached **DIY Secchi Disk Instructions**.

Investigation Setup Notes

- If students have limited experience with experimental design, or if you would prefer to emphasize conducting the investigation rather than planning it, consider developing the design as a class or providing students with a basic procedure.
  - See the attached **Procedure Example** for an example of more detailed investigation instructions for students.
- Make sure you have collected a sufficient amount of pond water or order a fast-growing algae culture ahead of time.
  - If using pond water, remove large grazers (like *Daphnia*) by pouring the water through a fine mesh of window screen (mesh size should be around 200 µm).
- For reliable comparisons among variables and groups, use a consistent setup (e.g., 500 mL of pond water in a plastic water bottle).
  - This allows the class to use a single set of controls vs. needing a control for each group of students.
- Expect the experiment to last at least 5–10 days, depending on the initial concentration of algae and phytoplankton community composition.

Explore 1: Phytoplankton Functional Groups

Once students have started the investigation, distribute a set of the attached **Phytoplankton Cards** to each investigation group. Have students compare the cards with the microscopic views of the four lakes' phytoplankton communities to identify the number of each type of phytoplankton found in each lake.

Next, students should use the genetic factors listed in the table on each card to sort the phytoplankton into groups.

Content Notes and Prior Knowledge

- Phytoplankton are single cells or colonies, so they don't have tissues or organs.
- It is assumed that students already understand the concept that genotype influences phenotype.
    - Take a moment to activate this prior knowledge—review how genes in the phytoplankton's DNA determine not only what the phytoplankton looks like, but also the strategies it uses to survive (especially since phytoplankton do not have a brain).

Once the cards are sorted, students should record their sorting factor and list the phytoplankton in each group. Then, students should choose a second factor, sort the phytoplankton again, and record their factor and list of phytoplankton in each group. Have students sort phytoplankton in this way for a minimum of three factors.

Student Answers and Teacher Response

- As you observe student conversations about functional groups, take note of:
    - what characteristics they use for categorization, and
    - how they think these characteristics relate to the phytoplankton communities in each lake.
- Check with groups on what they know about what determines phytoplankton characteristics (i.e., whether they are making the prior knowledge connection that characteristics are genetically determined).

Explain 1

After students have finished sorting phytoplankton for a minimum of three factors, they should compare their sorted lists of phytoplankton with the groups of phytoplankton within each lake community, taking note of any patterns or relationships.

Content Notes

- Phytoplankton are extremely diverse, and algae scientists have struggled to find the best method for categorizing species in ways that explain their role in ecosystems. When algae scientists categorize phytoplankton by physical characteristics or survival strategies, they call them "functional groups."
- Like other organisms, phytoplankton adapt to their environment via natural selection. Thus, the categories students used to organize phytoplankton have ecological meaning.

Once groups have had time to make their comparisons, bring them together to discuss as a whole class. Have students describe the ecological significance of the genetic factors listed on each card (e.g., being able to use more than one resource means they have more nutrients available than functional groups that cannot use more than one). Ask students what they can conclude about the phytoplankton in each of the four lakes. If relevant, this is a good opportunity to help students take notes and make connections between the activity and other ecology concepts they may have learned previously.

Next, ask students: In what kind of environment would we find each phytoplankton group (functional group)? Be sure to focus specifically on nutrient conditions (high, low, both conditions) at some point during the discussion.

Once pairs and groups have made sense of their data, ask students to revise their initial models based on the evidence they have collected. If genetic factors were not included previously, students should add them at this point.

Formative Assessment

- Take a moment to assess student models, either formally or informally. Note the changes they make and whether the revised relationships are consistent with their experimental evidence and analysis of phytoplankton characteristics.
- Look for the inclusion of both environmental and genetic factors in student models. If genetic factors were not included previously, students should add them after the phytoplankton card sort activity.

Explore 2

Once the water clarity experiments from Explore 1 are complete, create experiment focus groups or "factor expert panels" by combining groups that tested the same variable in their investigation. These groups should compile and compare data from their experiments. They should treat their individual investigations as replicates and use them to calculate averages that summarize their collective data.

Based on this data, each group should develop a claim about their results (e.g., "[Our experimental factor] results in [some result]"). Note that water clarity is most likely to be influenced by nutrient resource levels. To prepare for the class discussion, groups should create a figure that displays their results summary as a graph and includes their claim in a caption.

Discussion and Analysis Support

- A potential scaffold to aid student analysis and discussion is Data Match, especially if students are novices at translating numbers and graphs into scientific ideas.

Formative Assessment

- To assess student understanding, listen to students' conversations as they analyze and make sense of their data. Take note of:
    - how students are organizing their data (a line graph is ideal),
    - the patterns and trends students identify, and
    - what variables and relationships students connect to their results.
- Pay attention also to the confidence students have in their results. Many times, when experiment outcomes are other than expected, students believe that "human error" is to blame.
    - If this is the case, ask students which other variables might affect phytoplankton growth that they *did not* test to help them understand that sometimes unexpected results are due to things that weren't measured rather than mistakes.
- Work with each student group to make sure its final graph and claim are correct, as all students will use this information to continue to develop and revise their models.

Similarly, these experiment focus groups should compare their phytoplankton classifications and comparisons with the phytoplankton community data for each lake. While groups do not need to create any visuals for use in the class discussion, they should have a list of claims with supporting evidence from their analysis.

Explain 2

At this point, the class should work together to create a Concept Card Map that synthesizes what students have learned so far about the relationships among water clarity, environmental factors, and phytoplankton growth. Before groups share their ideas, post the images of lake water that were used to introduce the phenomenon. Add the nutrient and environmental variables from students' experiments as concepts to help anchor their ideas.

Ask all groups to share their claims and evidence from their experiment results and have them add their graphs to the concept map. Next, have students share their claims about phytoplankton functional groups and communities.

As students share their ideas about the relationships among phytoplankton characteristics, environmental variables, and the phenomenon, ask students to use evidence to (1) add new concepts to the map, and (2) identify the relationship(s) among existing concepts.

Concept Map Facilitation

- Each time students add an idea, they should include their evidence and explicitly connect the new concept to at least one other concept on the class concept map.
  - For physical concept maps, have students put their claims and ideas on index cards or sticky notes. Provide string or markers (as appropriate) for students to physically indicate relationships among variables and concepts.
- Make sure that all relationships indicated on the concept map are correct and that all connections are supported by available evidence.

Once all groups have shared, give them some time to identify any other relationships or concepts that they think should be added to the map to capture what they've learned so far.

Discussion Support

- Help students develop ideas and resolve misconceptions by modeling constructive science talk and providing students with discussion scaffolds (e.g., talk moves or the Talk Science Resource Cards linked in the Engage section).
- Consider developing your own concept map in advance. Identify complex relationships (e.g., indirect causes) and determine what simple ideas students need to understand to figure out the bigger picture.
  - If students get stuck, ask them guiding questions about the simple ideas first and then build up to the complex ideas as they make sense of each piece.
- If misconceptions persist, provide mini-lectures that focus on specific gaps in understanding as needed.

Once the class concept map is complete, students should use the compiled information and relationships discussed to revise their model again. The revisions should explain the cause-and-effect relationships that influence phytoplankton growth and water clarity. Remind students that they should draw a model that shows how changes to the variables they tested in their investigations affect water clarity, even if the connections are indirect.

Now that students are aware of a number of variables, rephrase the instructions for creating a model to emphasize cause-and-effect relationship chains. “Draw a diagram that shows how changes to one component of the system affect components that are not directly connected to that component” (STEM Teaching Tool #41).

Formative Assessment

- When assessing student models, pay attention to the changes students have made to their models. These changes must be consistent with the evidence presented on the class concept map and include both environmental and genetic factors.
- Also note how students use scientific ideas to summarize or indicate relationships within the model (e.g., competition, resource availability, growth, and reproduction).
    - Target your guiding questions and positively reinforce ideas that demonstrate thorough understanding in discussion with individual students here. Reemphasize these ideas in the Extend section of the lesson as well.
- Use your assessment to address any remaining misconceptions or incorrect ideas that persist among students.

Before moving to the Extend section, ask students to make a prediction about the nutrient conditions for each of the four lakes. If students investigated other factors (e.g., light), they could also use these as part of their predictions.

Extend

Once students have a consistent and correct understanding of the environmental and genetic factors that affect phytoplankton growth, which influences water clarity, distribute the attached **Four Lakes' Data Reports**.

It is recommended that you use one of these water quality reports to model how to interpret the information.

Content Notes

- Based on nutrient levels, Tecumseh Lake is an outlier with nitrogen levels as high or higher than Lake Thunderbird. In this case, phytoplankton growth is limited by light availability instead of nutrient concentrations.
  - If groups tested light levels in the experiment, this may already be part of students' models. If not, this is an opportunity for them to consider the red color of the water in Tecumseh Lake.
- This lake demonstrates the feedback loop created by water clarity. As water clarity decreases, less light is available for photosynthesis.
  - While this is not necessarily the focus of this lesson, it does provide a segue into lessons on photosynthesis and respiration, human impacts through landscape use, and even the development of design solutions to maintain biodiversity and ecosystem services.

Students will use a Venn diagram to compare and contrast their predictions with the "Parameters" data in the reports. Creating the Venn diagram provides students with the opportunity to evaluate their models.

After students have evaluated their models, have a class discussion about their evaluations. Encourage students to use their evaluations to further revise their models.

Discussion Support

- Based on student responses, you may elect to discuss the purpose and limitations of models. Remind students that models are a simplification of a complex system where multiple variables contribute to a phenomenon.
- Some students may believe a model is "wrong" if it does not accurately predict all possibilities. Use this discussion to reassure students that creating a model is a process. Scientists often learn the most when something unexpected happens; at first, success often looks like failure.

Evaluate

Have students pick one of the lakes other than Tecumseh Lake. They should use their model to explain the question posed in the Engage section. To ensure that students' answers are thorough, it is recommended that you use the two sub-questions:

- What factors cause phytoplankton to grow?
- How do those factors indirectly affect water clarity?

Be sure that students reference the evidence that supports their model.

Students may choose to deliver their explanation as a paragraph, storyboard, stop-motion animation, or video. Have students present their explanations or curate them for other students to watch/read independently (e.g., gallery walk, Flipgrid, Padlet, school LMS). After completing their own explanation, students should evaluate one or more peer explanations.

How you formally assess the final explanation (e.g., rubric, checklist, etc.) will depend on the format options students have to choose from, but the scoring should address connections among ideas and use of evidence rather than quality of presentation.

Assessment Criteria

Regardless of how you choose to assess students, it is recommended that at a minimum students include and support the following with evidence in their answers:

- a clear statement about how both genetics and the environment contribute to phytoplankton growth in their lake,
- at least one environmental factor in their lake that directly influences phytoplankton growth,
- at least one environmental factor in their lake that indirectly influences phytoplankton growth,
- at least one genetic factor that influences phytoplankton growth and its ecological relevance to their lake, and
- an explicit connection between phytoplankton growth and water clarity in their lake.