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 the water clarity as some lakes being "dirtier" than others.
- Students may ask questions or make observations about the amounts of mud, dirt, leaves, trash, and pollutants in the water.
- If students don't mention algae or phytoplankton, consider guiding them toward this idea or introduce it as a factor with the next set of images.

Continue engaging students with 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 the water. Explain the basic definition of water clarity as well. Direct students to look for patterns in the phytoplankton communities and add these ideas and questions to the previous list.

Guide students to consider what might cause increasing amounts of phytoplankton in the water 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.

- Students should mention that water, light, carbon dioxide, and nutrients help plants grow.

- Students may mention plant food or fertilizer instead of nutrients. If so, introduce nutrients as building blocks to make more cells. Explain that the most common nutrients plants need are nitrogen and phosphorous.

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At this point, ask students to what they've observed and discussed to draw a model that explains the phenomenon. Tell students that in this less they will respond to the questions "How do genetic and environmental factors influence the growth of organisms?" and "How does phytoplankton growth 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
  - 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
  - whether students consider both environmental and genetic factors within their models.

Explore 1: Investigation

Teacher's Note: Student Notebooks
Have students record their data collection in the "Phytoplankton Investigation" section and the "Roles in Phytoplankton Communities" section in the **Student Notebook** handout.

Ask students to look at the growth factors they included in their models that they think affect phytoplankton growth. Ask them how they can test one of these growth factors to see if their idea is correct. Have students plan and carry out an experiment in small groups. Have them test a single variable that may affect phytoplankton growth. Ensure that more than one group is assigned to each variable (e.g., two groups are assigned to test nitrogen, three groups are assigned to test phosphorous) so that groups can later combine their data for analysis.

Ensure that some groups test increased nitrogen, increased phosphorous, or an addition of fertilizer that contains both nitrogen and phosphorous. If other students want to test light levels, pH, temperature, or other factors, consider adding these. Have students record phytoplankton abundance daily. Consider using a modified Secchi disk, which is the most efficient method for this process. For a demonstration of how to use a Secchi, watch the YouTube video *The Dirty Labcoat: The Secchi Stick*.

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

Teacher's Note: Investigation Setup
- If students have limited experience with experimental design, or if you would prefer to emphasize conducting an investigation rather than planning it, consider developing the experiment design as a class or provide students with a basic procedure.
- See the attached **Procedure Example** document for an example of detailed investigation instructions for students.
- Ensure that 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. The mesh size should be around 200 μm.
- Use a consistent set up between variables and groups to ensure a reliable comparison (e.g., 500 mL of pond water in a plastic water bottle for each group and variable).
  - This process allows the class to use a single set of controls rather than a using a control for each group.
- Plan for this experiment to last between 5–10 days. The length of the experiment depends on the initial concentration of algae and phytoplankton community composition.

Explore 1: Phytoplankton Functional Groups

Once students have started the investigation, distribute one 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. Have them identify the number of each type of phytoplankton found in each lake. Next, have them use the genetic factors listed in on each card to sort the phytoplankton into groups.

Teacher's Note: Content Notes and Prior Knowledge

- Phytoplankton are single cells or colonies, so they don't have tissues or organs.
- Students should already understand the idea that genotype influences phenotype.
- Activate students' prior knowledge prior during this phase. Review how genes in the phytoplankton's DNA determine not only what phytoplankton look like, but also the strategies they use to survive, especially since phytoplankton do not have a brain.

Have students record the factor they used to sort the phytoplankton and have them list the phytoplankton in each group. Have them then choose a second factor, sort the phytoplankton again, and record the factor and list the phytoplankton in each group again. Repeat this process at least once more to have students sort the phytoplankton by a minimum of three factors.

Possible Student Responses

- As you observe student conversations about functional groups, take note of which characteristics they used to categorize the phytoplankton and how they think these characteristics relate to the phytoplankton communities in each lake.
- Prompt groups to consider what determines phytoplankton characteristics. Help them activate the prior knowledge connection that characteristics are genetically determined.

Explain 1

Have students compare their sorted lists of phytoplankton with the groups of phytoplankton within each lake community. Tell them to take note of any patterns or relationships.

Teacher's Note: Content Notes

- Phytoplankton are extremely diverse, and algae scientists have struggled to find the best method to categorize species in ways that explain their roles in an ecosystem. When algae scientists categorize phytoplankton by physical characteristics or survival strategies, they refer to them as "functional groups."
- Like other organisms, phytoplankton adapt to their environment via natural selection, so the categories used to organize them have ecological meaning.

Bring students together to discuss their comparisons as a whole class. Have students describe the ecological significance of the genetic factors listed on each card (e.g., groups that can use more than one resource have more nutrients available than groups that cannot use more than one).

Ask students what they can conclude about the phytoplankton in each of the four lakes. Consider using this opportunity to help students make connections between the activity and other ecological concepts you have previously studied.

Ask students to consider in what kind of environment each functional group of phytoplankton could be found. Invite students to share out responses and facilitate a discussion. During the discussion, ask students to consider whether environments should have high, low, or a mix of high and low nutrients.

Invite students to revise their initial models based on the evidence they collected. If they did not include genetic factors previously, encourage them to add those factors at this point.

Formative Assessment

- At this time, formally or informally assess student models. Note the changes they made during their revisions. Observe whether their revised relationships are consistent with their experimental evidence and analysis of phytoplankton characteristics.
- Look for the inclusion of both environmental and genetic factors in students' models. If genetic factors were not included, encourage students to add them now.

Explore 2

Create experiment focus groups, or "factor expert panels," by combining groups that tested the same variable in their investigations. Have these new focus groups compile and compare their data. Tell them to consider each original group's investigation as replicas of the same investigation and use this data to calculate averages that summarize their collective data.

Have each group use this data to develop a claim about their results. Tell groups to prepare for class discussion by creating a figure that displays their results summary as a graph. Have them include their claim as a caption for the graph.

Teacher's Note: Discussion and Analysis Support

Consider using the Data Match instructional strategy as a potential scaffold to aid student analysis, especially if students are new to translating numbers and graphs into scientific ideas.

Formative Assessment
- Formatively assess students' understanding by listening to their conversations as they analyze their data. Take note of how they are organizing their data (a line graph is ideal), the patterns and trends they identify, and what variables and relationships they connect to their results.
- Pay attention to the confidence students have in their results and how they interpret the outcome. Often, if an experiment's outcome is other than what is expected, students believe that it is a result of human error.
  - If students achieve unexpected results, ask them to consider which other variables, which weren't measured, might affect phytoplankton growth. Help them understand that unexpected results could be due to other factors rather than mistakes.
- Work with each student focus group to ensure that final graphs and claims are correct.
- Ensure that each focus group discusses their phytoplankton classifications and comparisons for the phytoplankton communities in each lake. Encourage each group to prepare a list of claims with supporting evidence for the class discussion.

Explain 2

Have the class work together to create a [Concept Card Map](#) that synthesizes what students have learned about the relationships among water clarity, environmental factors, and phytoplankton growth.

Begin the activity by posting the images of lake water that were initially used to introduce the phenomenon. Include the nutrient and environmental variables from students' experiments as concepts to help anchor their ideas. Ask groups to share out their claims and evidence from their experiment results and have them add their graphs to the concept map.

As students share their ideas about the relationships among phytoplankton characteristics, environmental variables, and the phenomenon, ask them to use evidence to add new concepts to the map and identify the relationships among existing concepts.

Teacher's Note: Concept Map Facilitation

- When students add an idea to the concept map, ensure that they include any evidence and explicitly connect the new concept to at least one other concept on the map.
- If creating a physical concept map, have students put their claims and ideas on index cards or sticky notes. Provide string or markers, depending on your needs, for students to physically indicate relationships among variables and concepts.
- As students identify relationships, ensure that the connections they make are correct and supported by evidence.

Once all groups have shared, allow them time to identify any other relationships or concepts they think should be added to the map to illustrate their learning.

Teacher's Note: Discussion Support

- Help students develop ideas and resolve misconceptions by modeling constructive science talk and providing students with discussion scaffolds (e.g., the Talk Science Resource Cards linked in the Engage phase).
- Consider developing your own concept map in advance. Identify complex relationships (e.g., indirect causes) and determine which basic ideas students must understand to see the bigger picture.
  - If students appear stuck, ask guiding questions about basic ideas and build to the complex ideas.
- If misconceptions persist, identify and fill in specific gaps in knowledge as needed.

Once the class concept map is complete, have students examine and revise their models again. Ensure that these revisions explain the cause-and-effect relationships that influence phytoplankton growth and water clarity. Remind students that their models should show how their tested variables affect water clarity, even if the connections are indirect.

Rephrase the instructions for creating a model to emphasize cause-and-effect relationship chains. Rephrase the instructions to something similar to the statement, "Draw a diagram that shows how changes to one component of the system affect components that are not directly 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 should include both environmental and genetic factors.
- Note how students use specific ideas to summarize or indicate relationships within the model (e.g., competition, resource availability, growth, and reproduction).
    - Positively reinforce ideas that demonstrate thorough understanding as you assess student models. Reemphasize these ideas in the Extend phase as well.
- Address any remaining misconceptions or incorrect ideas that persist among students.

Before moving to the Extend phase, ask students to make a prediction about the nutrient conditions in each of the four lakes. If students investigated other factors, such as light, they could include these factors in their predictions.

Extend

Once students have an understanding of the environmental and genetic factors that affect phytoplankton growth, which influences water clarity, distribute the attached **Four Lakes' Data Reports**. Consider using one of these water quality reports to model how to interpret the information.

Teacher's Note: 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 during 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.
- Tecumseh Lake demonstrates the feedback loop created by water clarity. As water clarity decreases, less light is available for photosynthesis.
  - While this is not the focus of the lesson, this information provides a segue into lessons on photosynthesis and respiration, human impacts through landscape use, and the development of design solutions to maintain biodiversity and ecosystem services.

Have students use a Venn diagram to compare and contrast their predictions with the parameters data provided in the reports. The Venn diagram allows students the opportunity to evaluate their models.

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

Teacher's Note: 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, in which multiple variables contribute to a phenomenon.
- Some students may believe a model is "wrong" if it does not accurately predict all possibilities. Use the discussion to reassure students that creating a model is a process. Tell them that scientists often learn the most when something unexpected happens, and that success may look like failure.

Evaluate

Have students select one of the lakes on the Four Lakes' Data Reports other than Tecumseh Lake. Tell them to use their model to explain the question posed in the Engage phase. To ensure that students' answers are thorough, have them address the two sub-questions, "What factors cause phytoplankton to grow?" and "How do those factors indirectly affect water clarity?"

Emphasize that students must reference evidence that supports their models. Tell them that they may choose to deliver their explanation through a paragraph, storyboard, video, or even stop-motion animation. Have students present these explanations or collect them in one location, such as your school LMS, for students to read or watch independently.

Have students evaluate one or more of their classmates' explanations. Determine your method for formally assessing the final explanation (e.g., rubric, checklist, etc.) and ensure that your scoring method addresses connections between ideas rather than quality of the presentation.

Teacher's Note: Assessment Criteria

Regardless of how you choose to assess students, ensure that student explanations include and support the following with evidence:

- A clear statement about how both genetics and the environment contribute to phytoplankton growth in their chosen 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
- An explicit connection between phytoplankton growth and water clarity in their lake.

Resources

Algae Research and Supply. (2016, June 15). *The dirty labcoat: The Secchi stick* [Video]. YouTube. https://www.youtube.com/watch?v=du1PA0pzdnQ

STEM Teaching Tools. (n.d.). Talk resource tools: Card sets. https://stemteachingtools.org/sp/talk-resource-cards