Temperature & Chlorophyll-a in Algae

9th & 10th Grade

Lesson Duration: 6, 42 minute periods

Introduction to Research & Advance Science Research
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BIG IDEAS

Chlorophyll-a, *Chlorella vulgaris*, Photosynthesis, Climate change, Human impacts on environment, Remote sensing data

EDUCATION STANDARDS

HS-LS1-5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

NGSS Performance Expectation(s)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
Developing and Using Models: Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. ▪ Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-5)	**LS1.C:** Organization for Matter and Energy Flow in Organisms ▪ The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HSLS1-5)	**Energy and Matter:** Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-LS1-5)
Common Core State Standards: **Interpreting Categorical & Quantitative Data S-ID:** Summarize, represent, and interpret data on two categorical and quantitative variables 5. Summarize categorical data for two categories in two-way frequency tables. Interpret relative frequencies in the context of the data (including joint, marginal, and conditional relative frequencies). Recognize possible associations and trends in the data. 6. Represent data on two quantitative variables on a scatter plot, and describe how the variables are related. a. Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models. b. Informally assess the fit of a function by plotting and analyzing residuals. c. Fit a linear function for a scatter plot that suggests a linear association.		

MEASURABLE STUDENT LEARNING OBJECTIVES

- Students will be able to ask questions using remote sensing data to determine the relationship between temperature and chlorophyll-a.
- Students will be able to plan and conduct a study to determine how temperature impacts the production of chlorophyll-a in algae cells.
- Students will be able to construct a claim using evidence and reasoning to describe how temperature impacts chlorophyll-a in *Chlorella vulgaris*.
- Students will be able to transform local remote sensing data into a line graph to calculate the linear relationship between temperature and chlorophyll-a.
- Students will be able to synthesize information from the unit to model how temperature impacts chlorophyll-a in phytoplankton.

STEM INTEGRATION

This lesson will incorporate elements from Science, Math, and Art. In science, this lesson will have students explore topics in biology showing the relationship between temperature and chlorophyll-a concentration. To integrate math, students will analyze their collected data and construct a bar and line graph of the data to present the information. To integrate art, students will design a model as the final assessments. By incorporating Science, Math, and Art into this lesson, students will authentically engage in integrating the elements of STEM into their work.

NATURE OF STEM

This lesson has students critically engage in the eight core understandings of the Nature of Science (National Research Council, 2013). During the ‘Engage’ phase, students will be observing patterns within the chlorophyll-a and sea surface temperature data from Nasa Earth Observatory. Using this remote sensing data, students will ask “questions about the natural world” (National Research Council, 2013) with partners about the patterns in the data. By drawing patterns within the data, students will recognize the idea that “scientific knowledge assumes an order and consistency in natural systems” (National Research Council, 2013). During the ‘Explore’ phase, students will have an opportunity to plan an investigation around how chlorophyll-a is directly affected by changes in temperature. Through the investigation of the experiment, students will acknowledge that “scientific investigations use a variety of methods” (National Research Council, 2013). During the ‘Explain’ phase, students will engage in the nature of science by analyzing their data to provide "empirical evidence” (National Research Council, 2013) of the phenomena. During the ‘Elaborate’ phase, students will extend their learning to local chlorophyll-a data on the Manhasset Bay.During the ‘Evaluate’ phase, students will present a model by choosing between google slides, bioRender, or poster paper. Presenting and communicating ideas publicly acknowledges the final core tenet of the nature of science in that “science is a human endeavor”. By incorporating the nature of science, students will have an opportunity to “enhance their knowledge and understanding of the natural world” (National Research Council, 2013).

MATERIALS NEEDED

• Pencils • Desktop computer • Microsoft Excel • IBM SPSS v. 28 • 10% bleach • Goggles • Lab aprons • 100 mL beakers • 250 mL beakers • 1000 mL beakers	• LabQuest 3 • *Chlorella vulgaris* obtained from Carolina Biologica • Vernier temperature probe • Glass petri dish • ImageJ • Incubator • Transfer pipettes • Autoclave

• 100 mL graduated cylinders • 1000 mL graduated cylinders • Digital scale • Weigh paper • Poster paper	• Go Direct® SpectroVis® Plus Spectrophotometer • Cuvettes • Lab notebook • Post-its • BioRender

ENGAGING CONTEXT/PHENOMENON

Manhasset students have become increasingly aware of this change in our local ecosystem, which relies on the health of Manhasset Bay. According to a study by Thibodeau et al. (2024), algae biomass has decreased by nearly 50% over the past 60 years (Thibodeau, et al., 2024). This is reflected by data from NASA's Earth Observatory from which shows changes in chlorophyll-a over the oceans. This has devastating impacts for the aquatic food chain which relies on phytoplankton as a food source.To combat this, Manhasset Research students have begun studying changes in temperature to the Manhasset Bay and our local algae population to propose solutions on how to address this problem.

DATA INTEGRATION

There are two types of data that will be integrated into this lesson: remote sensing and student generated data. For remote sensing data, information will be incorporated from NASA Earth Observatory and NOAA Coast Watch New York - New Jersey Bight & Long Island Sound Satellite Data. This data has students observe patterns of chlorophyll-a and surface water temperature globally and locally. For student generated data, students will be expected to collect data in a lab notebook and take photos of each procedure in the lab. Students will then transform their own data collected into graphs and data tables. Incorporating both remote sensing and student generated data allows students to authentically engage in science.

TEACHER BACKGROUND KNOWLEDGE

For this lesson, teachers should understand the relationship between chlorophyll-a and temperature. Teachers should study the cellular structure of *Chlorella vulgaris* to determine where chlorophyll-a is found in the cells, as shown in Figure 1 (Saif, et al., 2014). Teachers should review laboratory assays such as culturing *Chlorella vulgaris* using alga-grow as the nutrient source to simulate upwelling. Lastly, teachers should also understand how to calibrate and use the GoVis Spectrophotometer to calculate chlorophyll-a using peak wavelengths. By having a strong foundational knowledge base in practical laboratory application, teachers can be a more effective mentor for student laboratory activities.

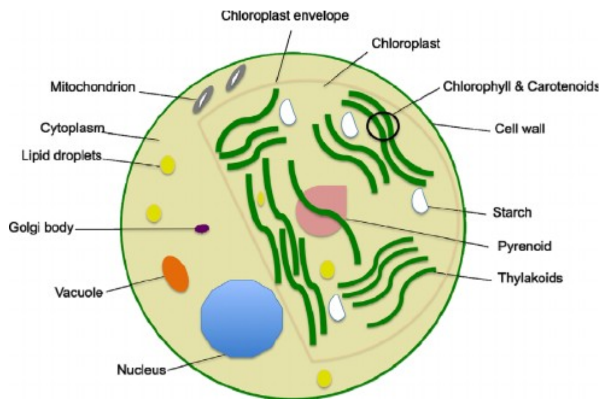

Figure 1: structure and organelles of Chlorella vulgaris cell (Safi, et al., 2014)

DIFFERENTIATION OF INSTRUCTION

When differentiating instruction, there are many scaffolds that can be utilized. Students can use the Wonder of Science graphic organizers when constructing questions and creating methodology for the laboratory investigation. These documents allow for a structured guide for students to engage in these aspects of research. Students may also use the provided videos to clarify the methodology and statistical analysis. Incorporating video guides can help students who are audio and visual processing learners access the content. Providing scaffolds during the learning process can help all students engage in science.

For the final evaluation assessments, a rubric will be provided as a scaffold. During instruction, all students can access the rubrics with a breakdown of points. The rubric helps reinforce specific components and keep the grading process clear for students. Lastly, students also have access to examples. Using examples provides students with a visual representation of the expectations for the posterboard. Incorporating rubrics and models into the lesson can differentiate the lesson for all students to engage in.

REAL-WORLD CONNECTIONS FOR STUDENTS

The lesson on temperature and chlorophyll-a creates multiple opportunities for students to connect the content to local issues. Locally, students can connect the idea of chlorophyll-a to nearby waterways that can create algal blooms. Many students at Manhasset are involved in the rowing and crew team that utilize the Manhasset Bay for practice. Understanding the impact of microplastics on the water quality for leisure activities can empower students to become involved in addressing this issue. In addition, students can become involved in local initiatives and laboratories through the Cold Spring Harbor Lab. Making connections to the real-world can help students become more engaged in our science labs.

INTEGRATION POSSIBLE MISCONCEPTIONS

In order to effectively plan a 5E lesson, teachers should pre-emptively address misconceptions about chlorophyll-a in algae. One common misconception is that colder temperatures are harmful for aquatic organisms and warmer temperatures are beneficial to stimulate chlorophyll-a growth.

As outlined by the NASA Earth Observatory, when “sea surface temperatures are often cooler than nearby waters, and chlorophyll concentrations are higher” (NASA, Earth Observatory, 2025). This is due to deep water rising, bringing vital nutrients to phytoplankton. When surface water temperatures are warm, nutrients from the deep ocean cannot rise and therefore phytoplankton production is limited. By anticipating student’s misconceptions, teachers can ensure that students are successful in science.

LESSON PROCEDURE

5E	Details of 5E Lesson Implementation
Engage	**Procedure:** The teacher will instruct students to observe remote sensing data from NASA Earth Observations (NEO) on Chlorophyll from 2002-2025. Independently, students will write down five observations from the data. As students are working, the teacher will help circulate and encourage students to deepen their thinking. Then, students will share with a partner their findings and generate three testable research questions about the data. Before sharing, the teacher will introduce the temperature data for students to overlay. In partners, students can revise their questions, making sure to have the questions link temperature and chlorophyll-a concentration. As a class, students will share one question their group created about the data. The teacher will guide the conversation by writing all questions on poster paper. When all questions are shared, students will decide on one question to use as the class goal for this topic. **Objective:** Students will be able to ask questions using remote sensing data to determine the relationship between temperature and chlorophyll-a. **Modifications:** Students can use the "Asking Questions" template from the Wonder of Science as a tool to organize their testable questions. **Formative/Summative Assessment:** Teacher will evaluate student questions to modify the investigation based on the patterns students have observed in the data. **Materials:** Desktop computers, lab notebook, pencil, post-its **Resources: Asking Questions Graphic Organizer.pdf** https://earthobservatory.nasa.gov/global-maps/MY1DMM_CHLORA

	https://earthobservatory.nasa.gov/global-maps/MYD28M/MY1DMM_CHLORA
Explore	**Procedure:** Day 1 (Algae preparation): Prior to class, the teacher will sterilize Erlenmeyer flasks in the autoclave. At the beginning of class, the teacher will reinforce safety procedures for lab use. Individually, students will read through the Carolina Biologica algae culturing guide. In lab groups of 3-4, students will write down the procedure which will be checked by the teacher. In groups, students will inoculate the Chlorella vulgaris in three Erlenmeyer flasks with Alga-gro. Students will place each flask in three incubators: 15°C, 25°C, and 35°C. Students will record the procedure in a lab notebook as well as any observations. The teacher will circulate in the lab to ensure students are following the procedure and clarify any questions students have about the procedure. Day 2 (Data Collection): Individually, students will choose to either watch the Plant Pigment Spectra Using Go Direct SpectroVis Plus video or read through the Vernier Measuring OD600 guide on how to calibrate the Spectrophotometer. In lab groups of 3-4, students will write down the procedure which will be checked by the teacher. When students have a completed procedure, students will begin the lab. Students will follow the procedures to use a transfer pipette to collect a 1 mL of each algae sample in a cuvette to analyze in the Spectrophotometer. Students will open the Spectral Analysis program on the computer and connect the spectrophotometer. To begin data collection, students must change the excitation wavelength to 405 nm. Students will collect the data at a peak wavelength of approximately 675 nm in the lab notebook. Students will then create a table and a bar graph of the data. The teacher will circulate in the lab to ensure students are following the procedure and clarify any questions students have about the procedure. **Objective:** Students will be able to plan and conduct a study to determine how temperature impacts the production of chlorophyll-a in algae cells. **Modifications:** Students can use the “Planning and Carrying Out Investigations Graphic Organizer” from the Wonder of Science as a tool

	to organize methodology and collect data. Students can use the "Analyzing and Interpreting Data Graphic Organizer" from the Wonder of Science as a tool to organize data and build a graph. **Formative/Summative Assessment:** Teacher will evaluate student participation in the lab groups as well as data collected in the lab notebook. **Materials:** 10% bleach, Goggles, Lab aprons, 100 mL beakers, 250 mL beakers, 1000 mL beakers, 100 mL graduated cylinders, 1000 mL graduated cylinders, Digital scale, Weigh paper, LabQuest 3, *Chlorella vulgaris* obtained from Carolina Biologica, Vernier temperature probe, Glass petri dish, ImageJ, Incubator, Transfer pipettes, Autoclave, Go Direct® SpectroVis® Plus Spectrophotometer, cuvettes **Resources** Algae Care Guide: https://www.carolina.com/teacher-resources/Document/culturing-algae-instructions/tr29112.tr GoVis Spectrophotometer Instructions: https://www.vernier.com/til/18306?srsltid=AfmBOoqjWt9Pti69jBBk3-AqRkpVCE6joXAcH1vN5_jNBv7RlzYZNuns GoVis Spectrophotometer Video: https://www.vernier.com/video/plant-pigment-spectra-using-go-direct-spectrovis-plus/ Planning and Carrying Out Investigations Graphic Organizer: Planning and Carrying Out Investigations Graphic Organizer.pdf Analyzing and Interpreting Data.pdf
Explain	**Procedure:** Students will read through the NASA Earth observatory article from NASA on phytoplankton. Students will annotate and highlight the article for important information such as definitions. Students will make the connection that lower temperatures allow for an increase in upwelling which provides the nutrients for the algae. If students would like more information, they can use the Ecowatch Chlorophyll-a reading. Using the information, students will construct a

	"CER" based on the data collected in the lab and the information from the reading. With a partner, students will peer review each other's "CER" and provide feedback on ways to improve before revising. As students are working, the teacher will conference in small groups with students to reinforce their learning. **Objective:** Students will be able to construct a claim using evidence and reasoning to describe how temperature impacts chlorophyll-a in *Chlorella vulgaris*. **Modifications:** Students can use the "Engaging in Argument from Evidence Graphic Organizer" **Formative/Summative Assessment:** Students will engage in peer-review to evaluate a partner's "CER". Teacher will evaluate "CER" during conferences and at the end of the lesson. **Materials:** Pencils, Lab notebook, Desktop computer **Resources** Chlorophyll-a reading: https://ecowatch.noaa.gov/thematic/chlorophyll-a Phytoplankton Reading: https://earthobservatory.nasa.gov/features/Phytoplankton Engaging in Argument from Evidence Graphic Organizer
Elaborate	**Procedure:** With a partner, students will open the NOAA coastwatch website. Students will select Chlorophyll-a and select today's date. Students will use the map to determine the Chlorophyll-a concentration today in (mg/m^3) and for the past week in the Manhasset Bay. Students will then repeat the same procedure to record surface temperature in their lab notebook. On graph paper, in Excel, or in IBM SPSS, students will then create a scatter plot to create a correlation graph showing how temperature affects Chlorophyll-a concentrations locally. Students can then calculate a line of best fit for the data. The teacher will circulate and clarify any questions during the lesson. **Objective:** Students will be able to transform local remote sensing data

	into a line graph to calculate the linear relationship between temperature and chlorophyll-a. **Modifications:** Students can use the "Using Mathematical and Computational Thinking" Graphic Organizer to organize how to construct a scatter plot of their data. **Formative/Summative Assessment:** Teacher will evaluate student generated graphs. **Materials:** Desktop computers, lab notebook, pencil, IBM SPSS v. 28, graph paper **Resources:** Using Mathematical and Computational Thinking Graphic Organizer: Using Mathematic and Computational Thinking Graphic Organizer.pdf NOAA Coastwatch Data: https://eastcoast.coastwatch.noaa.gov/region_nl.php#chlor
Evaluate	**Procedure:** Teacher will introduce the culminating task by watching the Wonder of Science "Modeling Systems with Evidence" video. The teacher will review the rubric with students as a full class. Individually, students can choose between one of the following modes for creating a model of their findings: • Biorender • Poster Paper • Google Slides As students are working, the teacher will give individualized feedback to students about their models and clarify any questions. **Objective:** Students will be able to synthesize information from the unit to model how temperature impacts chlorophyll-a in phytoplankton. **Modifications:** Students can use the "Modeling Systems with Evidence Template" as a tool to organize the final model. **Formative/Summative Assessment:** Teacher will evaluate models

	based on the rubric provided below. **Materials:** Desktop computers, BioRender, Posterpaper **Resources:** Modeling Systems with Evidence Template: https://docs.google.com/presentation/d/17X5zsItBerckqfY63XevSuLKBig9n6yd0tEuyltu95g/template/preview Modeling Systems Video: Modeling Systems with Evidence

RUBRIC:

Criteria	**Possible Points**
Components	• 10 points: All components are illustrated and explained with labels • 7.5 points: Most components are included but some crucial aspects of the model are missing. All components have labels. • 5 points: About half of the components are included. Some labels are missing. • 2.5 points:Most components are missing. Some labels are missing. • 0 points: Components and labels are missing.
Relationships between the components of the model	• 10 points: All relationships are illustrated and explained with labels • 7.5 points: Most relationships are included but some crucial aspects of the model are missing. All relationships have labels. • 5 points: About half of the relationships are included. Some labels are missing. • 2.5 points:Most relationships are missing. Some labels are missing. • 0 points: Relationships and labels are missing.
Description of relationship	• 10 points: A description of each relationship is present with an explanation of the mechanism driving the relationship. • 5 points: A description of about half of the relationships are present. An explanation is given but lacks meaningful connections to the mechanism. • 0 points: A description of the relationship is missing.
Connections to phenomena	• 10 points: Clear connections to the phenomena are provided in the model. • 0 points: No clear connections to the phenomena are provided in the model.

MODEL WORK:

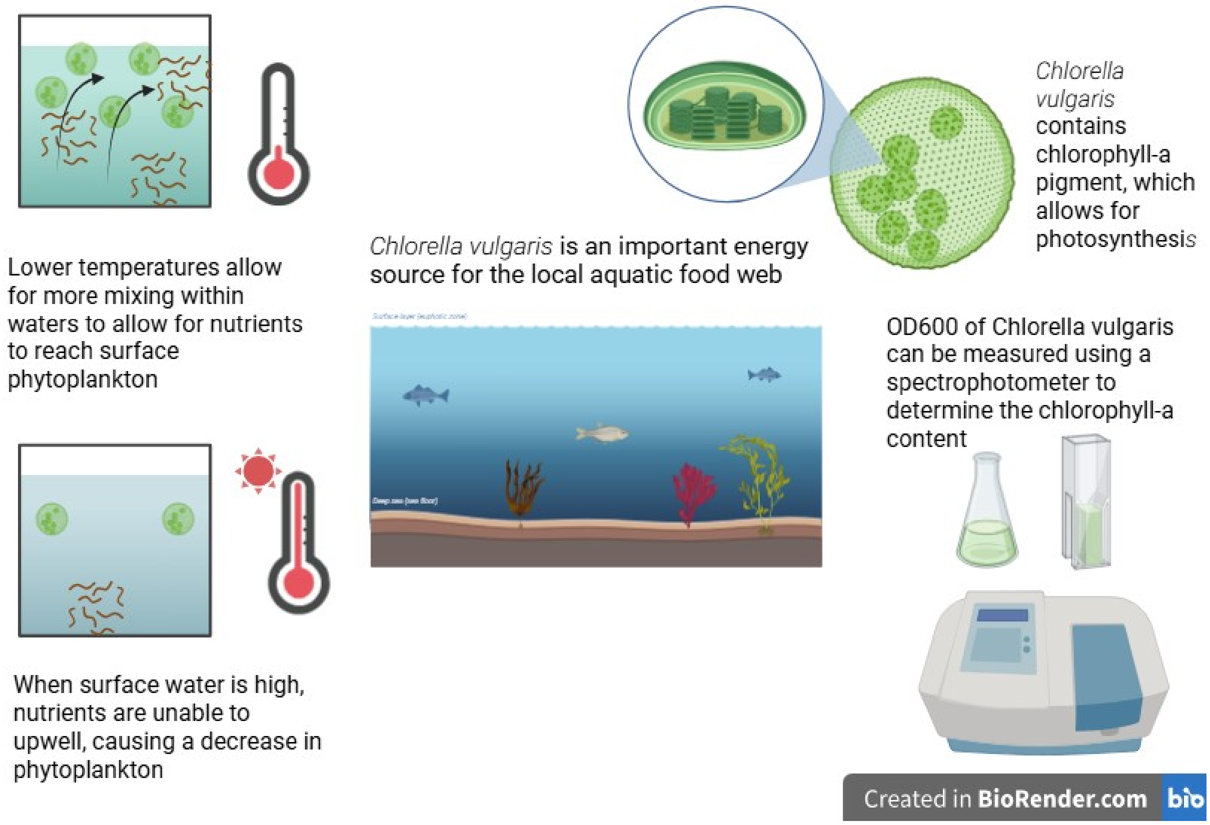

Figure 2: BioRender Model (Figure created by Manhasset students, 2025)

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