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Microscopy Is Worth a Thousand Words: A Curriculum on Phytoplankton

ACTIVITIES AND PROGRAM MODELS

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ABSTRACT

Phytoplankton play a pivotal role in marine ecosystems and provide essential ecosystem services. Rising ocean and air temperatures are contributing to oceanic conditions that support harmful algal blooms and are being documented at more frequent occurrences and for longer durations. The present curriculum, aimed for middle and high school students grades 7–12, focuses on aspects of phytoplankton ecology and supports student's conceptualization of microscopic phytoplankton and their roles in coastal ecosystems. The curriculum utilizes the five 'E's' (*Engage, Explore, Explain, Elaborate,* and *Evaluate*) to facilitate discussion, field activities, and measure student comprehension. Students discuss what is in the ocean, how it can be collected/observed, and how microscopic organisms, such as phytoplankton, can be identified using microscopes. Students will learn and practice proper field protocols, such as sample/data collection and laboratory procedures. Collecting field samples and allowing students to perform microscopy will support the final evaluation of producing a creative product to communicate the things that are not obviously visible in the ocean. Students will be evaluated through ocean literacy standards to explain how phytoplankton have the potential to negatively impact ecosystems and how these impacts may evolve. This curriculum is geared towards non-traditional classrooms, Tribal or coastal communities, field courses, and multi-generational gatherings or other learning environments that may support citizen science applications. Understanding and communicating phytoplankton's potential to be harmful can empower coastal community members to make informed harvesting decisions. Developing and utilizing climate-focused curricula supports fostering students who will go on to make climate-focused choices in their daily decisions, communities, and future careers.

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1. INTRODUCTION

Phytoplankton serve as the base of the food chain, performing almost all marine photosynthesis (Potera 2010). As climate change creates warmer oceanic temperatures, phytoplankton populations will experience both positive and negative changes, primarily through increased population blooms. While phytoplankton blooms have the potential to increase the base of the food web, they also can negatively impact the resources that coastal communities rely on, such as shellfish harvest (Roland et al. 2024). Over the last seven decades, Alaska has seen an increasing linear trend for statewide mean annual temperatures of approximately 4.3°F (~2.4°C) (ACRC 2024). Warmer temperatures may also create a longer season in which the ocean conditions are ideal for harmful algal blooms (HAB), increasing both the duration and breadth of bloom occurrences. HABs consist of phytoplankton that can produce dangerous biotoxins such as saxitoxin (STX) and domoic acid (DA), which are ingested by shellfish, and other filter feeding organisms, as they consume algae in their regular diet. HAB events can occur when sunlight, nutrients, temperature, and turbidity conditions combine and are likely to increase as ocean temperatures continue to rise. HABs are a topic of increasing concern in coastal Alaskan ecosystems. These blooms have potential to harm marine organisms via three vectors: harmless discoloration of water growing so dense that O_2 depletion causes fish kills (eg: *Noctiluca*, *Gonyaulax*), species can damage or clog fish gills (eg: *Chaetoceros*, *Heterosigma*), or species can produce potent neurotoxins that bioaccumulate through the food chain (*Alexandrium*, *Dinophysis*, *Pseudo-nitzschia*) (Bruslé 1995).

The present curriculum builds on pre-existing phytoplankton curricula adding to a myriad of non-traditional learning environments found in remote and coastal communities (Kast 2021; Kelly & Kast 2020; Pike 2022). A hands-on and interactive curriculum focused on phytoplankton supports the establishment of a bank of diverse pedagogies for education events focused on a theme that an educator can utilize over the course of an entire semester or season. This curriculum focuses on HABs, and their impact on important Alaskan (or general coastal) resources, such as shellfish, with an overarching theme of food webs. It emphasizes the biotoxin element of HABs and their impact on rural and remote communities. Objectives include recognizing algae as primary producers of the food web, displaying competency in conducting field collections and basic microscopy with proper lab safety, and communicating visualized results. Students will be evaluated based on their ability to communicate that the ocean and humans are inextricably interconnected and the human impact on ocean and atmosphere as (Halversen et al. 2021). Developing and utilizing climate focused curricula supports fostering students who will go on to make climate focused decisions in their daily decisions, communities, and future careers.

Educating youth in an engaging way is critical to develop the next generation of those who take positive climate actions. Young people aged 12 to 17 know and care more about the ocean and environmental issues, and they are more willing to act on environmental initiatives than adults (Ocean Project 2009). Youth serve as a unique subset to introduce climate concepts; however, in underserved schools even fewer students receive an adequate ocean education because there are limited funds to offer elective ocean science classes and to provide the necessary training and resources for their teachers (Cava et al. 2005). Furthermore, a lack of ocean literacy, (i.e., 'an understanding of the ocean's influence on you and your influence on the ocean') could result in the public making uninformed decisions for ocean or coastal communities that rely on waters that are adjacent to their communities (Cava et al. 2005; Winrow et al. 2021). Communities in Alaska that are closely tied to ocean ecosystems are often deeply connected to these ecosystems through culture and Traditional Ecological Knowledge (TEK).

Many Alaskan students, and their families, are regularly interacting, and exposed to, marine ecosystems through subsistence practices, commercial fishing, general recreation, and have generational TEK that has been passed down over time immemorial. Providing accessible curricula that focus on microscopic organisms, such as phytoplankton, and their impact on food webs, helps showcase the impact microscopic organisms can have as they are related to larger organisms and subsistence culture. Using phytoplankton as a building block for public health and large-scale ecosystem impacts in an interactive manner can enhance public knowledge and awareness of the ocean, thus increasing public support for ocean restoration efforts (Steel et al. 2005). Furthermore, increased knowledge and general awareness is attributed to increased individual responsibility when it comes to choosing environmental decisions that help the ocean (Plankis & Marrero 2010).

2. METHODS

2.1 LESSON PLAN

In chronological order, the present curriculum utilizes the "*Engage, Explore, Explain, Elaborate*, and *Evaluate*" format (Pike, 2022). Within each section (*Engage, Explore, Explain, Elaborate,* and *Evaluate*) an individual activity, group discussion, and group activity occurs. Existing Next Generation Science Standards (NGSS) science curricula focus mostly on terrestrial aspects, and teachers express discomfort with their knowledge and ability to teach topics relating to climate change and marine science, but express high interest in learning more (Madden et al. 2023). The present curriculum utilizes the NGSS aimed at students aged 12–18 years, or grades 7–12 (NRC 2013). It incorporates classroom discussion, field work/data collection, and introduces laboratory methods, and general lab safety skills. Each section is accompanied by a guiding question and can be accompanied by a beach walk before or during the activity. If laboratory and phytoplankton specimens are not available, alternatives are presented. (*Accompanying worksheets are presented as Figures*).

A. Materials

B. Engage

B.1. Individual Activity: Ocean Investigation (Figure 1, quadrant 1; Figure 2)

B.2. Group Discussion: What we find in the sea (Figure 2)

B.3. Group Activity: Ocean Inquiry (Figure 3)

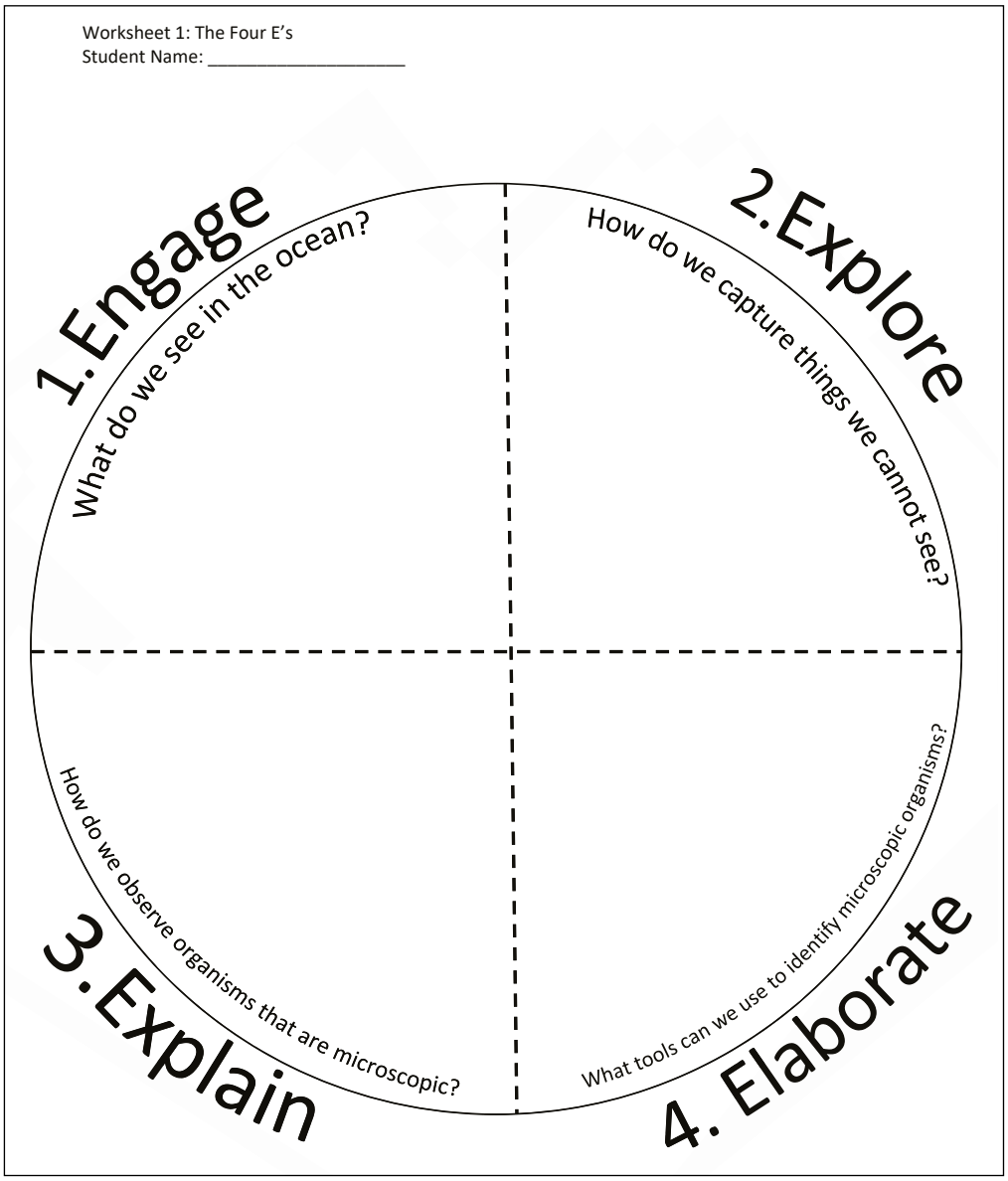


Figure 1 Worksheet 1: The four quadrants *Engage, Explore, Explain*, and *Elaborate* method providing guiding questions for the curriculum.

Worksheet 2: Ocean Investigation
Student Name: _____

QUESTION	RESPONSE
What items do you find in the sea that surprise you? Why?	
What do people look for in the ocean for food and income?	
What items are not visible from the ocean surface?	
What items do we find in the ocean that are not supposed to be there?	
What items do we know, or think are in the ocean, but we cannot see?	
What about those that are too small to be seen with just our eyes?	
Draw what you think phytoplankton looks like? *Choose from: Alexandrium spp., Pseudo-nitzschia spp., Dinophysis spp., or Chaetoceros spp.* *What does it actually look like?* 	

Figure 2 Worksheet 2: Ocean Investigation question and response activity.

C. Explore

C.1. Individual Activity: Introduction of phytoplankton tow (Figure 1, quadrant 2)

C.2. Group Discussion: Introduction of phytoplankton net

C.3. Group Activity: Conduct phytoplankton tow (Figure 3; Middleton et al. 2021)

D. Explain

D.1. Individual Activity: Observing microscopic organisms (Figure 1, quadrant 3)

D.2. Group Discussion: Lab safety

D.3. Group Activity: Lab preparation

E. Elaborate

E.1. Individual Activity: Tools for microscopy (Figure 1, quadrant 4)

E.2. Group Discussion: Microscopy discussion

E.3. Group Activity: Lab Activity

F. Evaluate

F.1. Assessment (Figure 4)

Worksheet 3: Ocean Inquiry
Student Name: _____

Are all things in the ocean good? Why or why not?	
Yes	**No**

Environmental Data						
Date	**Air Temp (°C)**	**Water Temp (°C)**	**Tide (H/L)**	**Salinity**	**Wind + Direction**	**Initials**

Figure 3 Worksheet 3: Ocean Inquiry – discussing the benefits and consequences of what is found in the ocean and collecting environmental data.

Worksheet 4: Incorporate
Student Name: _____

Incorporate what you have learned and practiced into a creative method to show, or explain, the things we cannot 'see' in the ocean.

How do these impact larger plants, organisms, and ecosystems? How might they change in coming years, decades, or generations?

Use the space provided to brainstorm or create your final product. Additional pages/mediums can be utilized.

Figure 4 Worksheet 4: Incorporating what students have learned through a creative evaluation.

2.2 LESSON OUTLINE

A. Materials

1. Worksheets (Figures 1, 2, 3)
2. Phytoplankton net (prefabricated or homemade) – choose one of the following:
   a) Building a plankton net (Kolb 1981)
   b) Catching Plankton (National Oceanic and Atmospheric Administration 2005)
   c) Planktonic Relationships! (Kelly & Kast 2020)
   d) OR 20–100 µm mesh plankton net [Sea-Gear Corporation, Melbourne, FL]
3. Thermometer (temperature range 32°F –100°F (~0°C – 37°C) range)
4. Sample bottle (125 mL bottle)
5. Refractometer [Hach Industries Inc., Pittsburgh, PA] (optional)
6. Pipette
7. Phytoplankton tow procedure (Middleton et al. 2021)

8. Pen or pencil
9. Microscope (10x eyepiece and three objectives –4x, 10x, 40x) [Olympus Corporation, Hachioji, Tokyo]
10. Slides/slide covers

If the worksheets provided are not being utilized, students can be encouraged to bring a (field) notebook to jot down ideas and activities.

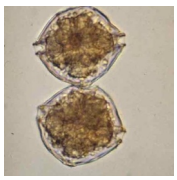
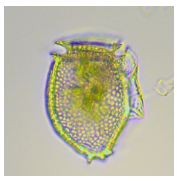
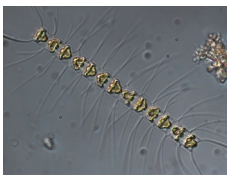
B. *Engage*: What do we see in the ocean?

The activity begins by asking a big picture question of 'What do we see in the ocean?'. Allow students approximately five minutes to fill this worksheet out: "The four E's" (Figure 1, quadrant 1). Allow a group sharing opportunity for personal experiences following this. General answers may begin with the macro flora and fauna (whales, otters, seals, etc.). This can be followed by asking, "What do they eat?". Follow up questions should challenge students to think of smaller items that exist in our ocean (fish, shellfish, phytoplankton, etc.).

B.1 Individual Activity: Ocean Investigation (Figure 2)

The following questions (Figure 2: "Ocean Investigation") can assist in this discussion or a sharing circle format. These questions should challenge students to get to the concept that there are microscopic items in the ocean and focus on the concept of plankton. The analogy of dust, or small particles, can help students who may not be familiar with this concept. A few specks of dust are hardly visible, but as dust builds up, it is easy to spot with the naked eye. Provide background information on phytoplankton as needed (Table 1). Ask students to pick one of the four phytoplankton discussed above and draw what they think it might look like on their Worksheet 2 (Figure 2 "Ocean Investigation"). To conclude the individual activity, pass around user guides such as the Marine Phytoplankton of South-Central Alaska to find the phytoplankton they chose to draw (Middleton et al. 2021). Ask students if their drawing looks similar or different to what the guide shows (Figure 2).

Table 1 Common Harmful Phytoplankton Found in Coastal Alaskan Waters.

ALEXANDRIUM SPP.	*PSEUDO-NITZSCHIA* SPP.	*DINOPHYSIS* SPP.	*CHAETOCEROS* SPP.
• Can produce paralytic shellfish toxins (i.e., saxitoxin), which may lead to Paralytic Shellfish Poisoning (PSP) • More than 30 recognized species • Found globally in coastal waters • Most concerning species in Alaska	• Can produce domoic acid, which may lead to Amnesic Shellfish Poisoning (ASP) • ~60 known species, with approximately one half being toxic • Linked to widespread fishery closures on the U.S. West Coast	• Can produce okadaic acid & dinophysistoxins, which may lead to Diarrhetic Shellfish Poisoning (DSP) • More than 100 recognized species • Linked to shellfish fishery closures	• Do not produce toxins • Have spines with serrated edges, can lodge in fish gill tissues, causing irritation (WHOI 2025) • Form chains that are coiled, curved, or straight
			
(Anderson 2025)	(WHOI 2025)	(Heil n.d.)	(Kudela Lab n.d.)

B.2 Group Discussion: What we find in the ocean (Figure 2)

1. What items do you find in the ocean that surprise you?
2. How do people utilize resources found in the ocean?
3. What items are not visible from the ocean surface?
4. What items do we find in the ocean that are not supposed to be there?
5. What items do we know, or think are in the ocean, but we cannot see?
6. What about those that are too small to be seen with just our eyes?

B.3 Group Activity: Ocean Inquiry (Figure 3)

Are all things in the ocean beneficial? Why or why not? (Figure 3). Students can be split up into two groups and tasked to debate this question, assign each group a side to debate. Following their breakout group discussions, have one student from each group provide a synopsis of their side of the 'debate'. Discussion should be geared to potential positive and negative effects in coastal ecosystems, food webs, and fishery-based economies in coastal and remote regions.

C. *Explore*: How do we capture things we cannot see?

The 'Explore' section's main goal is to introduce the concept of a phytoplankton tow and a phytoplankton net with the goal of obtaining an actual sample for detailed study. A 20–100 µm mesh plankton net can be used for this activity if accessible. Nets may be accessible from local academic or non-profit organizations or ordered from a net company [Sea-Gear Corporation, Melbourne, FL]. This section also introduces scientific measurements, such as the micron, a unit not traditionally used in day-to-day life. Prior curricula exist for students to make a homemade phytoplankton net (see materials list above; Kolb 1981; Kelly & Kast 2020). If integrating art into the activity, educators can add a relevant art activity on top of the traditional phytoplankton net demonstration.

C.1 Individual Activity

The activity begins by asking students a big picture question of 'How do we capture things we cannot see?' and/or 'How do we capture and see things that are too small for the naked eye?'. Allow students approximately five minutes to fill out Worksheet 1 (Figure 1, quadrant 2). Allow students time to answer this question and come up with creative solutions before introducing the phytoplankton net and microscope.

C.2 Group Discussion

Allow a group sharing opportunity following this. After the group discussion, introduce the concept of a phytoplankton net, pass the net around, and allow students to touch it, and see the mesh to further establish the micron unit of measurement.

1. Before demonstrating a phytoplankton tow ask students who they think may perform phytoplankton tows:
    1. Is it only scientists?
    2. What about people who may work at a hatchery or as a citizen scientist?
    3. If students are unfamiliar with these concepts, take time to explain these career paths and their importance in Alaska, or in coastal communities.
    4. What are precautions you can take when collecting samples in a marine environment?

C.3 Group Activity

Use the phytoplankton monitoring instructions linked in the materials list to conduct the tow (Middleton et al. 2021). First display a phytoplankton tow and follow up with asking if any students want to practice this. Allow students to practice a tow, record pertinent environmental data, and include this on Worksheet 3 (Figure 3). Students can use additional paper if needed. This sample will be used in the Explain/Elaborate sections, do not discard the sample.

Samples can be collected from a public access dock, or beach, and analyzed in a classroom, field lab, or contracted out if access to microscopes is limited. Check with local non-profits, universities, and agencies for potential partnerships and access to laboratory resources. If microscopes are not available, or you are unable to obtain water samples, images of phytoplankton could fill in for the microscopy section. Additionally, winter months are less likely to have high abundance in phytoplankton. Samples can be collected at times in which planktonic species are more abundant, and preserved with 5% Lugols iodine mixture or 50–70% isopropyl alcohol [Fisher Scientific, Hampton, NH] for later use.

D. *Explain*: How do we observe organisms that are too small for the naked eye to see?

D.1 Individual Activity

The activity begins by asking students a big picture question of 'How do we observe organisms that are too small for the naked eye to see?'. Allow students approximately five minutes to fill this out on Worksheet 1 (Figure 1, quadrant 3). Allow students time to answer this question and come up with creative solutions before sharing out to the group and introducing the microscopes.

D.2 Group Discussion

Allow students to share their answers from the individual activity and introduce lab safety. Guiding questions for lab safety section are below:

1. What does lab safety mean?
2. What does lab safety look like?
3. Have you ever been in a lab? What precautions did you take? How did you act in the lab?

D.3 Group Activity

After students have practiced collecting a phytoplankton sample, they will take the sample to their 'lab' or area where the microscopes are set up. This section focuses on lab safety and preparing a slide. Walk students through identifying the various parts of a microscope, how to care for, and properly maintain, a microscope and preparing and handling slides.

E. *Elaborate*: What tools can we use to identify microscope organisms and general lab procedures/practice)?

E.1 Individual Activity

The activity begins through asking students a big picture question of 'What tools can we use to identify microscopic organisms?'. Allow students approximately five minutes to fill this out on Worksheet 1 (Figure 1, quadrant 4). Allow students time to answer this question and come up with creative solutions before sharing out to the group and introducing the microscopes.

E.2 Group Discussion

Allow students to share their answers from the individual activity listed above.

E.3 Group Activity

Once students have familiarized themselves with lab safety, preparing a slide, and microscopy, they can begin to identify the phytoplankton in the sample. User guides can support student identification of common phytoplankton found in South-Central Alaska (Middleton et al. 2021). Allow students to take turns identifying phytoplankton and showing their peers what they have found. If available, set up multiple slides on multiple microscopes allowing students to visualize various slides (dependent on group and facility size). Finalize this section by teaching students the proper way to clean and store the materials used.

As students are utilizing the microscopes, facilitate dialogue using the questions below:

1. What surprises you while looking in the microscopes?
2. Do the slides look like what you expected? How is it different/similar?
3. What might impact the density of how many phytoplankton are on your slide or in your sample?

F. *Evaluation* & Assessment

The final section of the lesson challenges students to do the following (Figure 4):

> Incorporate what you have learned and practiced using a creative method to show, or explain, the things we cannot 'see' in the ocean. Use the following questions to guide your creative response.
>
> 1. How do these impact larger plants, organisms, and ecosystems?
> 2. How might they change in coming years, decades, or generations?

This section is intentionally vague to allow students maximum freedom and creativity. However, this is an opportune time to discuss elements of environmental or climate change that may be occurring in localized areas. Past examples of assessments are journal entries with drawings, creative dances, poems, and theatrical performance, and sharing words in traditional languages (Figure 4). Students will be evaluated using the provided rubric, developed in line with ocean literacy principles (Halversen et al. 2021). The rubric breaks competency down to three key components – 'Life in the Ocean', 'Oceanic Conditions', and 'Fieldwork'.

3. DISCUSSION

The development of a curriculum for 12–18-year-olds is a progressive way to introduce oceanographic concepts and expand the students' knowledge of ocean ecology and possible impacts of a changing climate. The present curriculum allows for flexibility and alterations depending on the audience structure, location, or time allotted. This curriculum has been implemented with middle and high school students and community elders at agency field labs that had both docks, or ocean access, and wet laboratory space. It also highlights the crucial role phytoplankton play in marine ecosystems and their potential for multi-trophic impacts (Machado et al. 2023). Phytoplankton account for approximately half of the Earth's primary productivity, and climate change will alter phytoplankton dynamics (Litchman & Klausmeier 2008). As HABs exposure increases in frequency and duration, the focus on biotoxins such as saxitoxin or the broader category of paralytic shellfish toxins is of increasing concern to Alaskan marine food webs and coastal communities in Alaska (Lefebvre et al. 2016; Roland et al. 2024).

While the NGSS provides curricula standards, The National Science Education Standards Content Standards for Science as Inquiry suggests there are four key components to Scientific Inquiry: ask a question, plan and investigate, utilize simple equipment, use data and communicate results (Council 1995; Lederman 2009). Blending individual activities and group activities allows students to explore scientific inquiry from multiple perspectives and appeals to various learning styles and personalities that may be present in a diverse or non-traditional classroom setting. The four sections - *Engage, Explore, Explain*, and *Elaborate*, allow students to first learn about phytoplankton before they practice field and lab work. Starting the curriculum with the *Engage* section allows students to share their initial understanding of marine ecosystems and bring their unique perspective to fellow students. Youth who are given more ownership over discovery have been shown to leave with a greater sense of involvement, collaboration, and a greater sense of personal gain and satisfaction (Clement et al. 2023).

The *Engage* and *Explore* sections provide students with the necessary background on how to conduct fieldwork, before practicing what they have learned through phytoplankton tows. Through asking questions and pulling from knowledge already held by the students, these sections allow teachers to build from students' prior knowledge and encourages students to become more curious and ask more questions (Lederman 2009). These sections begin to empower students to show them that science can be accessible, and they are scientists, a key notion to encourage students to pursue STEM careers and support climate positive solutions.

The *Explain* section provides hands-on laboratory practice to analyze the samples their classmates, and them, have collected. A guided inquiry approach brings in questions from the educator but allows students to come up with the conclusions supported by their data (Sadeh & Zion 2009). By seeing the ocean through the lens of a microscope, they will gain exposure to what lies beneath the surface level of the ocean and what was discussed during the initial questions of the *Engage* section. Having field and laboratory work that is different from what might be found in a traditional classroom supports youth who see themselves as scientists (Clement et al. 2023). By concluding with the *Elaborate* section, students are given an opportunity to synthesize what they have discussed and observed in a way that targets their learning style. Allowing students to share the knowledge they gained in a way that promotes self-efficacy supports solidifying an interest in science that goes beyond traditional evaluation methods (i.e., exams).

Ultimately, this curriculum provides students and educators with flexibility to adapt discussion and activities as students' needs, backgrounds, and interests vary. It focuses on a key component of the environment - phytoplankton, and their potential to impact marine ecosystems due to climate change. This flexibility, in pair with both field and laboratory hands-

on pedagogies, exposes students to a holistic model of learning that makes clear connections to the implication's phytoplankton can have on ecosystems, fisheries, and coastal communities. It empowers students through showing them that science can take many forms and can be communicated in various formats. The curriculum supports ocean literacy, or the relationship between individuals and the ocean, and encourages students to consider how each person can communicate and make responsible decisions that support the ocean and its valuable resources (Cava et al. 2005). When offered through a community setting, the curriculum can raise overall awareness of the potential impacts of biological processes such as HABs and the possible options for communities to manage these events to ensure food safety and security.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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