Save the Whales! Using Marine Research in Math and Science Classrooms

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ACTIVITIES AND PROGRAM MODEL

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ABSTRACT

During the 2019–2020 academic year, I participated in a yearlong professional development (PD) opportunity that resulted in a co-curricular unit developed in collaboration with a marine researcher, a math teacher, and a marine biology teacher. Together we created a unit of study for students to utilize authentic marine research data points. Using the 5E model of instruction and anchoring phenomena, we developed a sequence of learning events for students to connect biology concepts with current local context. In the fall of 2019, I implemented the learning unit we had created. The next school year, I adjusted the curriculum because of the global pandemic and subsequent distance learning. The 2021–2022 school year saw yet another revision and more synchronous learning in algebra and biology as students worked in both classes to develop their culminating project. In all three versions of our curriculum, students responded positively to the learning experiences. As an educator, I appreciated the opportunity to collaborate with other educators and learn from a marine researcher and found excitement in using authentic data in the classroom.

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INTRODUCTION

In August 2019, a colleague and I began our adventure with the Oregon Marine Scientist and Educator Alliance (ORSEA), a yearlong opportunity provided by Oregon Sea Grant and the Oregon Coast STEM Hub. This professional development opportunity gathered middle and high school math and science teachers and marine researchers at the Oregon Coast for a three-day intensive workshop, followed by monthly meetings throughout the year to develop and implement marine-focused educational units. Our first evening at the workshop, we met other teachers and marine science researchers and participated in an interactive session to learn about each other. The next morning, we were introduced to our working groups. Our task was to develop a learning unit to bring the research to the students in a meaningful way using the 5E model (Engage, Explore, Explain, Elaborate, Evaluate) and an anchoring phenomenon. During the subsequent school year, the two science teachers in our working group implemented our constructed unit. In 2020, I adapted the unit for distance learning, and in the 2021-2022 school year I modified our culminating event to keep it relevant and timely. The experience of working with other teachers and a researcher to develop a unit was unique for me and worthwhile. This paper explores the process of collaboration, the implementation of our learning unit, and the modifications I have made each year.

PROCESS

On the first evening of the workshop, participating teachers and researchers displayed posters they created sharing their research and backgrounds. Each of us walked around to speak with one another about our common interests as identified on these posters. In these interactions, we hoped to develop connections that would lead to the formation of project teams. At the end of the evening, we completed surveys with lists of potential matches. The leaders of the workshop then took those surveys and determined the best fits for these smaller workgroups. The next morning, our workgroups were announced. My group included my colleague in the math department at my school, a teacher of marine biology at a coastal high school, and a graduate student researching humpback whales. With the groups determined, we set out to develop learning units for the upcoming school year.

Each group (including several teachers teamed with a marine researcher) was tasked with developing a cross-curricular unit for math and science (in our case biology and marine biology) using the research from the group's marine researcher as the basis of the unit. The research provided real-life, authentic data and context. In order to successfully create a unit around this data, we first had to understand the research.

During our first meeting together, I struggled. I understood the marine research involved analyzing DNA samples from humpback whales to determine which breeding population the whale belonged to. I also recognized the concern around entangled humpback whales off the Pacific Coast. I just could not connect these two. After several rounds of questions, I began to make sense of the issue; there are three different populations of humpback whales that spend time on the Oregon Coast (feeding and migrating) and each of the populations is designated at a different risk level under the Endangered Species Act. Entanglement is a concern for all humpback whales. However, the concern is greatest for those in the population listed as endangered as they do not have the numbers to support loss of life in this manner. As a result, we need to develop management regulations to protect the humpback whales. If we use DNA analysis on tissue samples, we can better understand which populations spend time off our coast, and then assess the need for management. Our challenge was to create a unit where students could uncover this connection and then apply it in a meaningful way.

Our next step was to determine our learning goals for this unit. We determined students would use the context of humpback whale populations and entanglement to learn about DNA and genetic profiling. Next, we worked to identify the science standards we could address in this unit. Oregon standards are Next Generation Science Standards (NGSS) based, so we looked at the NGSS standards for science and our math colleague looked at the Common Core math standards (see appendix A).

After looking at our long list, we settled on four NGSS standards we felt could be the core of this unit:

HS-LS3-1 – Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

HS-LS3-3 – Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

HS-ESS3-4 – Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS-ETS1-3 – Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

The math component was more complicated. The math teacher and I hoped to teach this unit together, which would work best if we had the same students in both of our classes. In our school, though, students in biology can be in a variety of math classes. This is likely the situation in most schools. We decided to focus on algebra as that class had the most overlapping students. With the math class selected, the associated standards became more clear. Since we were working with data, we decided the best math standards included graphical representations of data.

With standards identified, we began building our unit. The ORSEA workshop organizers provided us with a suggested outline for unit development to integrate into this learning experience, which focused on anchoring phenomena and the 5E model. The 5E model places students at the center of their learning. In this approach to lesson and unit development, students begin with an anchoring phenomenon to engage them in the learning event. Anchoring phenomena set up the unit with a natural or real-life scenario that prompts questions that the students then work throughout the unit to answer. We decided on a video of an entangled humpback whale. This would provide imagery for the students and, hopefully, evoke a response in them to want to learn more so they could help these animals.

After the first work session, we returned to our larger group. We shared our anchoring phenomena ideas with everyone and listened to feedback. It was interesting to listen to different groups' approaches. We opted for a video as an anchoring phenomenon while other groups opted for using still photos or sets of data to engage students.

As an educator, I want students to see a purpose in learning and in how the learning event was constructed. With this in mind, I contemplated what kind of experience would be relevant for this learning unit. This brought me back to our data and our standards. What were we hoping the students would get out of this unit? What was our focus? One of the standards we chose was about human impact on our environment. Specifically, HS-ETS1-3 (from NGSS) asks students to "evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts." The entanglement of the whales in fishing and crabbing gear is a clear example of human impact. There are methods and techniques currently in use and more being developed to mitigate those impacts by reducing the likelihood of entanglement. Rather than just telling the students about these resources, we needed a way for them to uncover those strategies and then think about them. We also wanted our culminating event to simulate real life. We decided a mock Town Hall meeting was the best option for a culminating event for this unit. Students would represent stakeholders discussing strategies to reduce humpback whale entanglement events off the Oregon Coast. In representing stakeholders, students would also encounter the complexity of solving real-world problems, including the trade-offs and considerations because of the diversity of needs of different stakeholder groups.

With our evaluation component completed, it was time to return to the middle three Es, Explore, Explain, and Elaborate. Following guidelines from the workshop leaders, we developed lessons for students to explore humpback whales and the Endangered Species Act. Then, we asked students to dive into genetic fingerprinting using a resource from Howard Hughes Medical Institute (HHMI). This resource provided students a web-based lesson about the use of

DNA fingerprinting to solve elephant poaching scenarios. We supplemented this with a lecture (the Explain portion of the 5E model) on DNA and STRs (short tandem repeats), then explicitly connected STRs to the marine research data on the humpback whales. In the Elaborate component of the unit, students mapped the location of humpback whales from sample data to see the overlap in feeding areas among members of three different breeding populations.

With information about the whales, identification, location, and the dangers in their feeding areas, students would be ready to take on a stakeholder role and prepare for the Town Hall meeting.

We built our unit to be applicable to both General Biology and Marine Biology classes. Though many of the activities completed in General Biology are part of the learning progression for the Marine Biology class, the latter goes into more depth. The Marine Biology class also added a whale watching field trip to their experience. Due to safety and financial concerns, the General Biology classes were unable to participate in this activity. Even so, we taught the unit early in the school year to correspond with typical southward migration timing for our coastline. This timing turned out to benefit us greatly the first year, as it meant we had completed teaching the unit well before schools shut down due to the pandemic.

As part of the ORSEA program, we continued to work together during the school year with the use of a shared Google Drive and Zoom meetings. The culminating event for the ORSEA program was to be a celebration of sorts over a weekend in May at the coast. Unfortunately, we were in the midst of a global pandemic and meeting in person was not to be. Instead, we celebrated virtually by creating posters of our projects and sharing those posters in breakout rooms during a Zoom meeting. It was important for us to celebrate, and I enjoyed seeing the work my peers had done in a school year like no other.

OUTCOME AND IMPLEMENTATION OF SAVE THE WHALES!

As a result of our work in the ORSEA program, we developed a full learning unit for General and Marine Biology classes, with inclusion of algebra standards. The full learning unit, including links, worksheets, and handouts, can be found at: https://oregoncoaststem.oregonstate.edu/orsea/managing-whales-risk.

The following synopsis is for the General Biology learning unit.

Engage: We decided our anchoring phenomenon would be a video of an entangled whale. We found a video of a humpback whale being disentangled by a group of people off the coast of Alaska. This is a short video (less than a minute) with little dialogue. After showing the video, we asked students what they thought was happening. We followed this with a video from the National Oceanic and Atmospheric Administration (NOAA) explaining more about whale entanglements and NOAA's efforts to disentangle the whales.

Explore: Students conducted online research to learn about the humpback whales and the Endangered Species Act. We created two guiding worksheets for the students to use as they explored different websites for this information. Students also completed the HHMI Biointeractive "CSI Wildlife" to learn about the use of DNA fingerprinting (genetic fingerprinting) used in solving crimes against African elephants (https://www.biointeractive.org/classroom-resources/csi-wildlife). For a hands-on activity, students extracted DNA from strawberries. On the student handout we included questions connecting the lab activity to humpback whales.

Explain: After students conducted their own research and completed the Biointeractive, we provided a lecture about some of the science concepts in this unit. In particular, we taught using a Google Slideshow about DNA and genetics. This lecture connected these concepts with their implementation in humans, elephants (as seen in the HHMI activity), and humpback whales.

Elaborate: With the groundwork set, we introduced the data from the marine researcher. This data consists of genetic profiles of specific humpback whales feeding off the Oregon Coast. The data identifies each whale's breeding group based on genetic alleles, specifically identified STRs used for genetic identification within the whale populations. Using this data, students created mock gel electrophoresis bands and mapped the locations of the DNA samples using the latitude and longitude coordinates included in the data (see Figures 1, 2, and 3).

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Figure 1 Halsey Randall, M. (2019). Students working in groups using marine research data of humpback whales to create mock gel electrophoresis bands and location maps. Used with permission of the photographer.

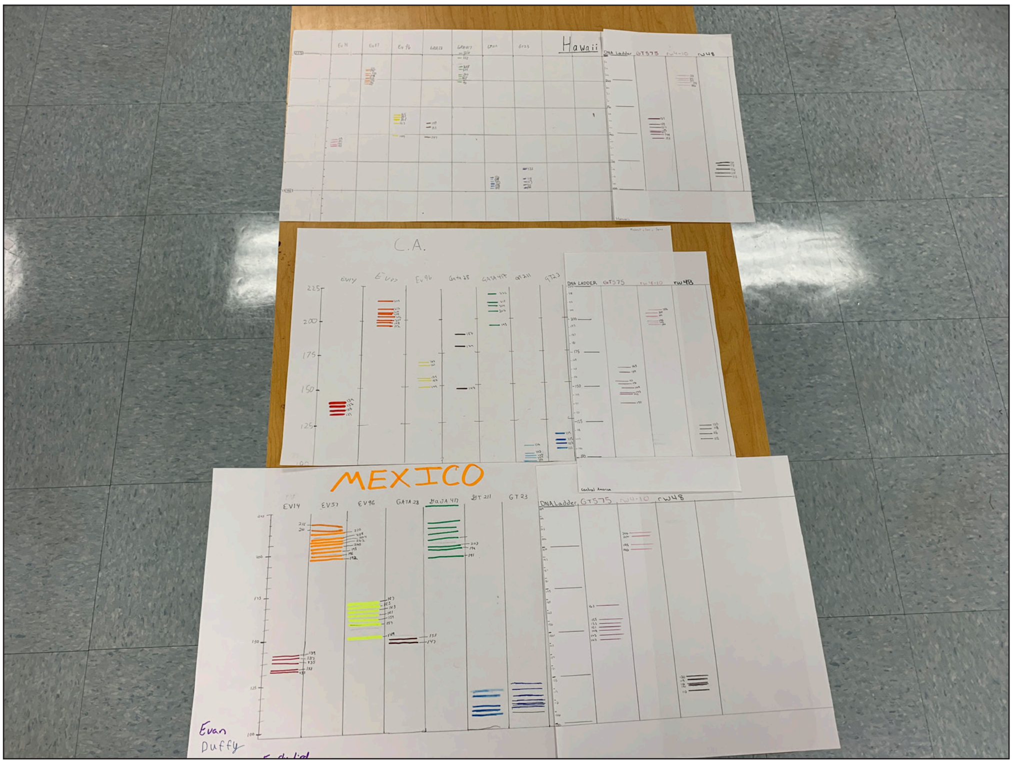

Figure 2 Halsey Randall, M. (2019). Student example of mock gel electrophoresis bands from the research data. Used with permission of the photographer.

Evaluate: In the first year of implementation, students conducted a mock Town Hall meeting and created visual aids to use during the meeting (see Appendix B for the visual aid template). Small groups represented stakeholders in the discussion of what to do about whale entanglement. Each stakeholder group prepared information about why they care, what they think should be done, what they are willing to do, etc. The first year I taught this unit, the Town Hall meeting was a perfect culminating event. The student groups immersed themselves in their roles, took the time to research what that stakeholder group would bring to the table, and listened to one another with passion and interest.

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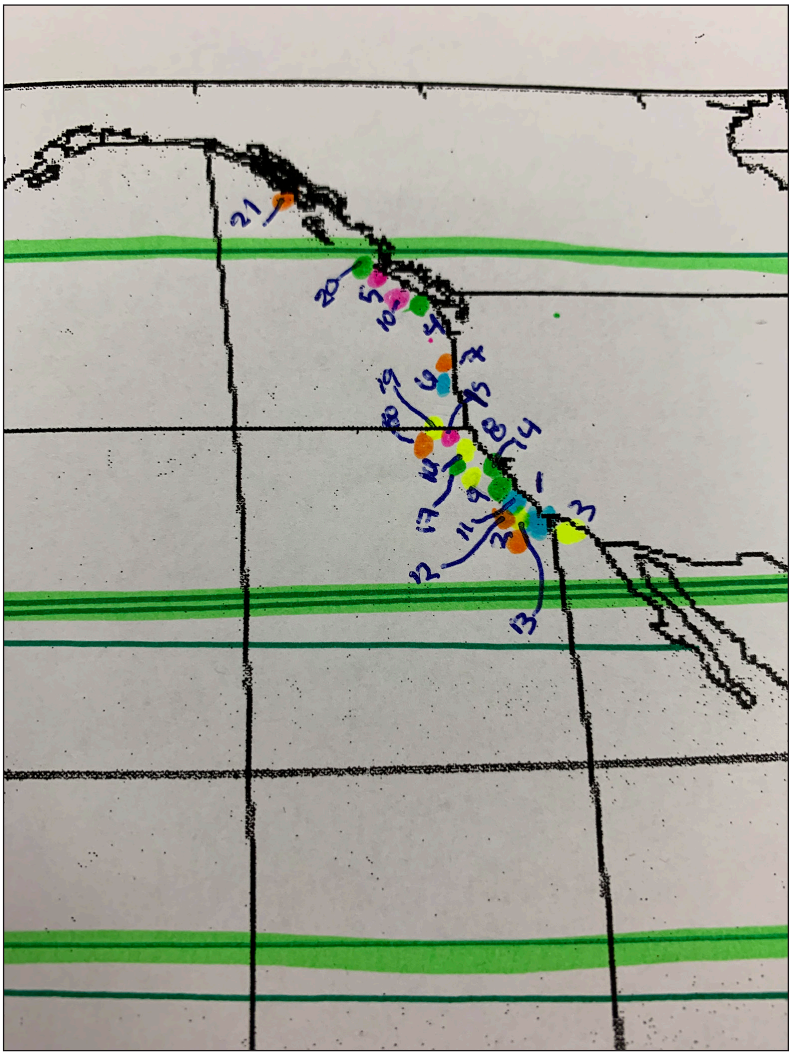

Figure 3 Halsey Randall, M. (2019). Map of locations of collected DNA samples along the Pacific Coast of North America. Used with permission of the photographer.

A few weeks after our mock Town Hall meeting, we discovered one of our nearby coastal towns was having an actual Town Hall meeting about this issue! After we read a short news story about the meeting, one of my students said, "Do you have recording devices in here because that sounds a lot like what we did in class." It was exciting to see students make the connection between the classroom and real-life.

In addition to the Town Hall meeting, students completed a short written assessment consisting of a few transfer questions. These asked students to develop an argument from a stakeholder lens about a different organism in a different time period.

MODIFICATIONS

Although the real Town Hall was so exciting in year one, I worried the mock Town Hall meeting would be less meaningful for year two if I set it up in the same way. Now that regulations were being developed to reduce the likelihood of whale entanglements in fishing and crabbing gear, asking students whether regulations should be in place did not feel adequate. I had to make a change. As is often the case in education, we adapt our lesson plans from year to year.

Year two of this unit required a lot of adapting. This was the year of distance learning due to the COVID-19 pandemic. We made a few adjustments to the learning activities in the unit, and added a virtual field trip (we watched a spectacular whale watching video on YouTube: https://www.youtube.com/watch?v=qTsXfGVjm1w&t=2s). We also found out NOAA changed the way it was tracking and reporting humpback whale populations. The year we wrote our worksheets, whale population data was available for the breeding populations of interest to us. However, the next year those numbers seemed impossible to find online. After my students complained about how much time they had spent scouring the web, I decided to give it a try. Sure enough, I could not find the data we had asked for on the worksheet. So, I called our local NOAA office.

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When I told the students that I had picked up the phone and called NOAA, they were shocked. I found it quite amusing how they reacted to my problem solving. The phone call was incredibly helpful and I obtained the information we needed. The students also learned an unexpected lesson about the benefit of human interaction.

The biggest change to the unit, besides being done during distance learning, was the evaluation. I decided to finish the unit with a written assessment rather than a Town Hall meeting or group project (see Appendix C). This approach gave me another year to figure out an alternative to the Town Hall, but I was worried that the students would not have the same positive reaction to the unit. However, when year two's class heard the students of year three were in the "Save the Whales!" unit, they were so excited for them. Several students said it had been their favorite unit of the year and the most memorable. This reaction let me know it wasn't just about the culminating event, but about the learning opportunities along the way.

Year three brought us back to the classroom. The math teacher and I decided we would attempt to teach this unit simultaneously, meaning the math component would be taught in her classroom at the same time I was wrapping up the unit in the science classroom. It was a large undertaking to coordinate this collaboration. In previous years, the math component was taught later and the "Save the Whales!" unit was referred to during the math piece, but there was no overlapping product or project to connect the two classes simultaneously. In year three, though, we developed a plan to make the timing work.

One hurdle we had to overcome was that not all of the students in biology were also in algebra and vice-versa. Our rosters did not match, so we added a new component. In the algebra class, students worked on developing data representations such as graphs. In biology, students were assigned groups with at least one group member also being in algebra class. This student became the "data consultant." The data consultant worked to develop the graphs, or data representations, for their biology group and explain the biology to their algebra groups.

The math teacher and I had all of the logistics worked out and were excited to start having the students work on these collaborative culminating projects. There was one catch: I did not know what I wanted the project to be. I had not contemplated how to adjust the Town Hall meeting topic to better reflect the current situation, nor did I feel a Town Hall meeting was right for this particular group of students. I wanted something students could connect with and see as meaningful and timely. I knew there had been recent changes to the use of the coastal waters as a result of the official Town Hall meetings a few years prior. So I created a project for students to develop and share a report on the health of the ecosystem off our coastline. Each group chose a different organism to report on. We created a scenario in which they were presenting their health status report to a committee. The new "Health of the Coastal Ecosystem Committee" consisted of the algebra teacher and me. Each group needed to report about their specific organism and then explain how that organism's health or status reflected the overall health of the ecosystem. Our goal was to develop a big picture of the current ecosystem to compare to in future years. This would help us understand if the recent regulations put into place to protect whales, specifically to reduce the risk of entanglement of humpback whales, would impact the overall health of the ecosystem of our coastline.

I brought this idea to the math teacher and she was ready to run with it. In math class, students could approach the data representation from multiple aspects. This was open-ended and allowed students to decide what numerical or statistical information was valid and worth including in their health reports, and decide the best form of visual representation for that data.

Just as happened with the first year of this project, our new culminating event matched reality. I was watching the news the evening after I introduced the project to my class and a marine biologist was being interviewed. Our coastline has become a potential location for floating wind farms. The marine biologist was telling the reporter how important it would be at this point to have an overall sense of the health of the ecosystem on and near our coastline. She explained what this meant, why it was important, and how this information would help determine any consequences we see in the future resulting from the wind farm. I could hardly believe what I was seeing! Of course, I showed my students this news clip the next day in class. This gave their projects even more meaning and context.

In addition to a presentation, student groups created handouts for the committee. These handouts included biology information as well as the data representations and explanations (see Appendix D). During the presentations to the committee, both biology and algebra students sat in the audience and also received the handouts. These were useful for both classes to see and be able to reference in their reflections on the project.

This version of our culminating event will remain applicable and relevant for years to come as there will be a need to continue to monitor the health of the ecosystem and begin to make comparisons across years. Though this year's groups did not have data from previous classes with which to compare their health information, I kept their handouts so that future classes might be able to draw conclusions and comparisons over the years as we see how the ecosystem changes.

REFLECTION

I was excited to participate in the ORSEA program. I had not had an opportunity to design an entire curricular unit with non-teachers before, nor had I had opportunity to interact with marine researchers. The outcome was incredible. I had often thought of collaboration as happening between teachers of the same students. However, this experience was more about collaboration between adults regardless of student rosters. We were working with one another to create lessons and learning goals applicable across content. It did not matter that one member of our group was from a different school or that the math and science classes did not share rosters. What mattered was that we contributed to the learning experience for one another by bringing our own expertise to the table. We valued each other's contributions and worked to create meaningful engagements for students.

The culminating events from this unit, both the mock Town Hall meeting and the Health of the Coastal Ecosystem Committee report, met my expectations. They were meaningful, relevant, and timely. Students engaged with these opportunities and made them memorable for those reasons. I strive to create meaningful lessons for students and am thrilled how well this one turned out, particularly with its relevance to current events in our communities. I could not have asked for a better connection to real life. Finding these connections and creating learning units where these connections can occur takes time: time for planning, time for implementing, and time for modifications. The outcome, though, makes the time invested worth it.

APPENDIX A: STANDARDS

STANDARDS – MATH

Math Practices:	CC Math Standards:
MP.1 – Make sense of problems and persevere in solving them.	HS.S-ID.5 – Summarize categorical data for two categories in two-way frequency tables. Interpret relative frequencies in the context of the data. Recognize possible associations and trends in the data.
MP.3 – Construct viable arguments and critique the reasoning of others.	HS.S-ID.6 – Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.
MP.5 – Use appropriate tools strategically.	HS.S-IC.1 – Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

STANDARDS – SCIENCE

HS-LS3-1 – Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

HS-LS3-3 – Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

HS-ESS3-4 – Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

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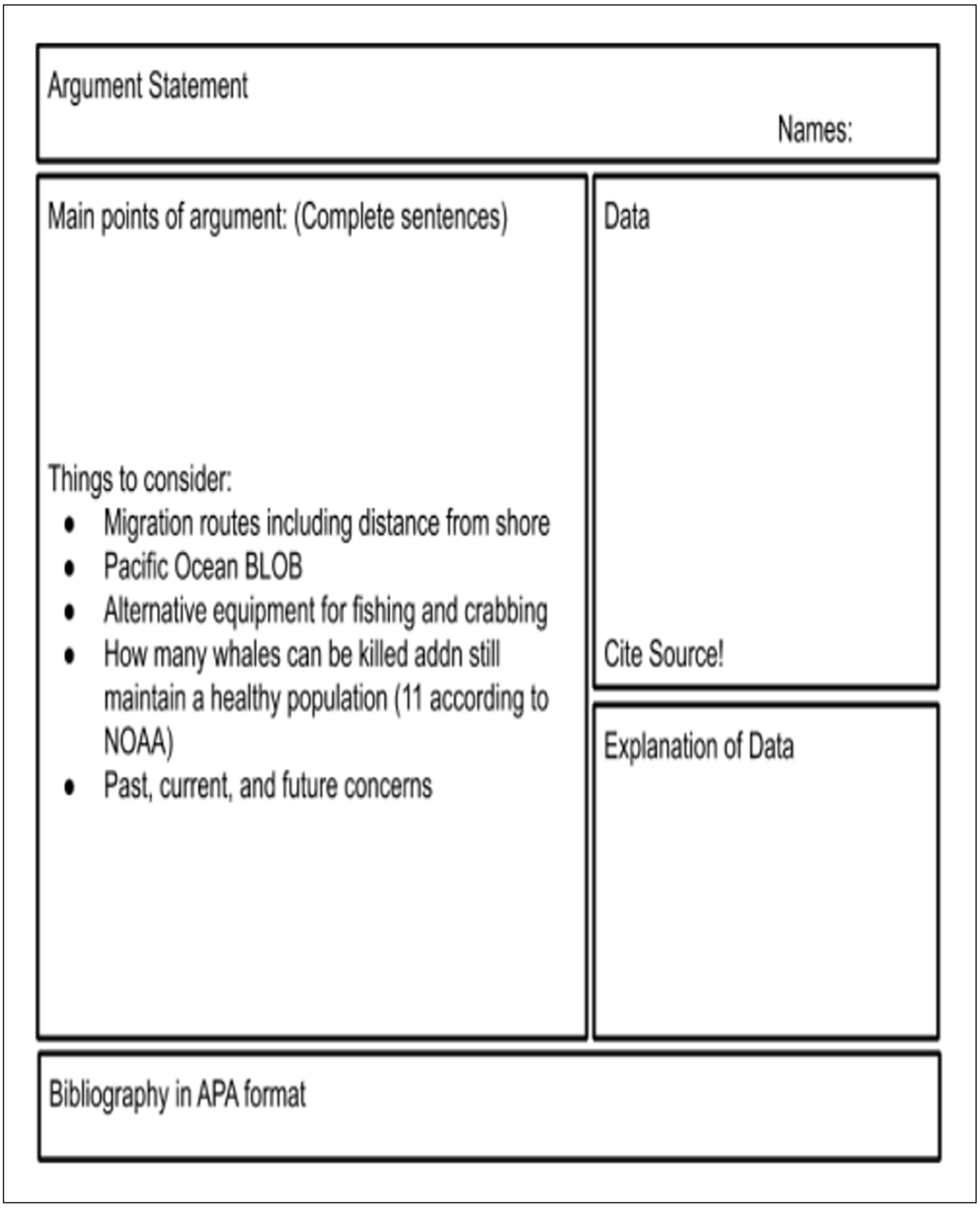
HS-ETS1-3 – Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Other Related Standards: *HS-LS2-6, HS-LS2-7, HS-ESS3-3, HS-LS2-2, HS-LS4-6*

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems	LS1.A – Structure and Function	Cause and Effect
Analyzing and Interpreting Data	LS3.A – Inheritance of Traits	Scale, Proportion and Quantity
Constructing Explanations and Designing Solutions	LS3.B – Variation of Traits	Stability and Change
	ESS3.C – Human Impacts on Earth Systems	Influence of Science, Engineering, and Technology on Society and the Natural World
	ETS.1B – Developing Possible Solutions	

APPENDIX B: TOWN HALL MEETING VISUAL AID TEMPLATE


Argument Statement

Names:

Main points of argument: (Complete sentences)

Things to consider:

- Migration routes including distance from shore
- Pacific Ocean BLOB
- Alternative equipment for fishing and crabbing
- How many whales can be killed addn still maintain a healthy population (11 according to NOAA)
- Past, current, and future concerns

Data

Cite Source!

Explanation of Data

Bibliography in APA format

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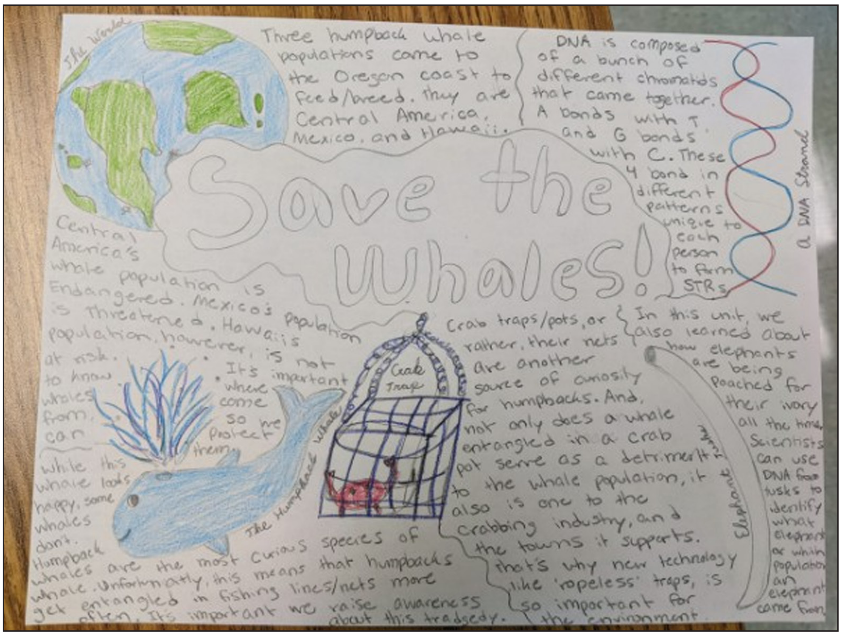
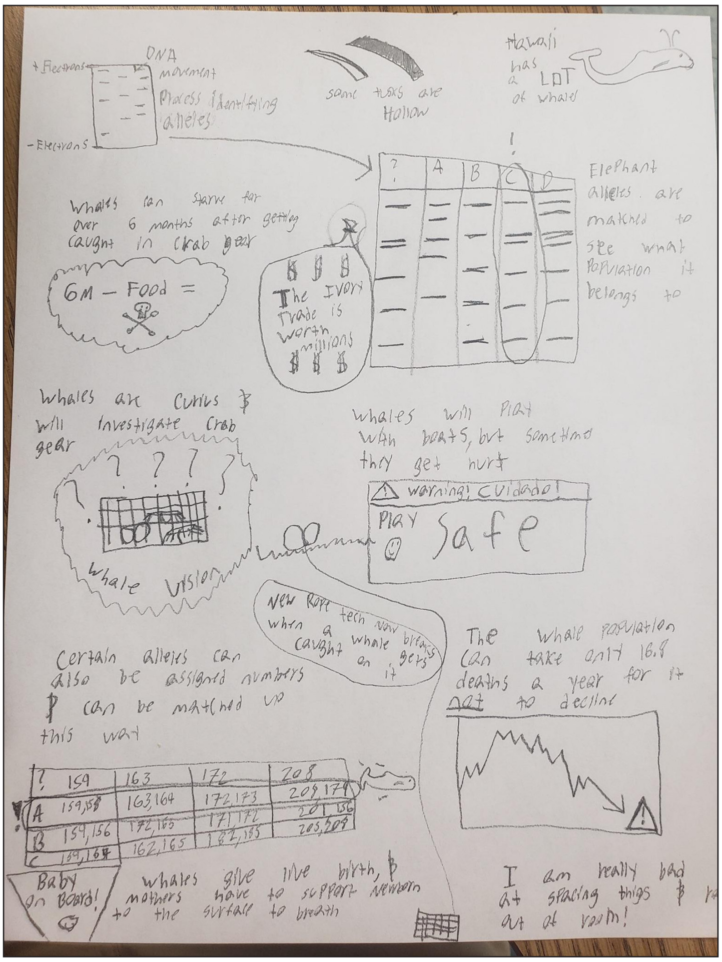
APPENDIX C: ASSESSMENT YEAR TWO

Directions: On a separate piece of paper, create a nature journal entry about this unit. First, close your notes and work from what you know. Take time to illustrate (humpback whales, elephants, DNA, tusks, crab gear, etc.), use color, define terms, write thoughts about what you have learned, etc. Use this time to put EVERYTHING you have connected with from this unit onto paper, especially information not already presented on this assessment. Be sure to include your ideas, opinions, or feelings about how we address whale entanglements.

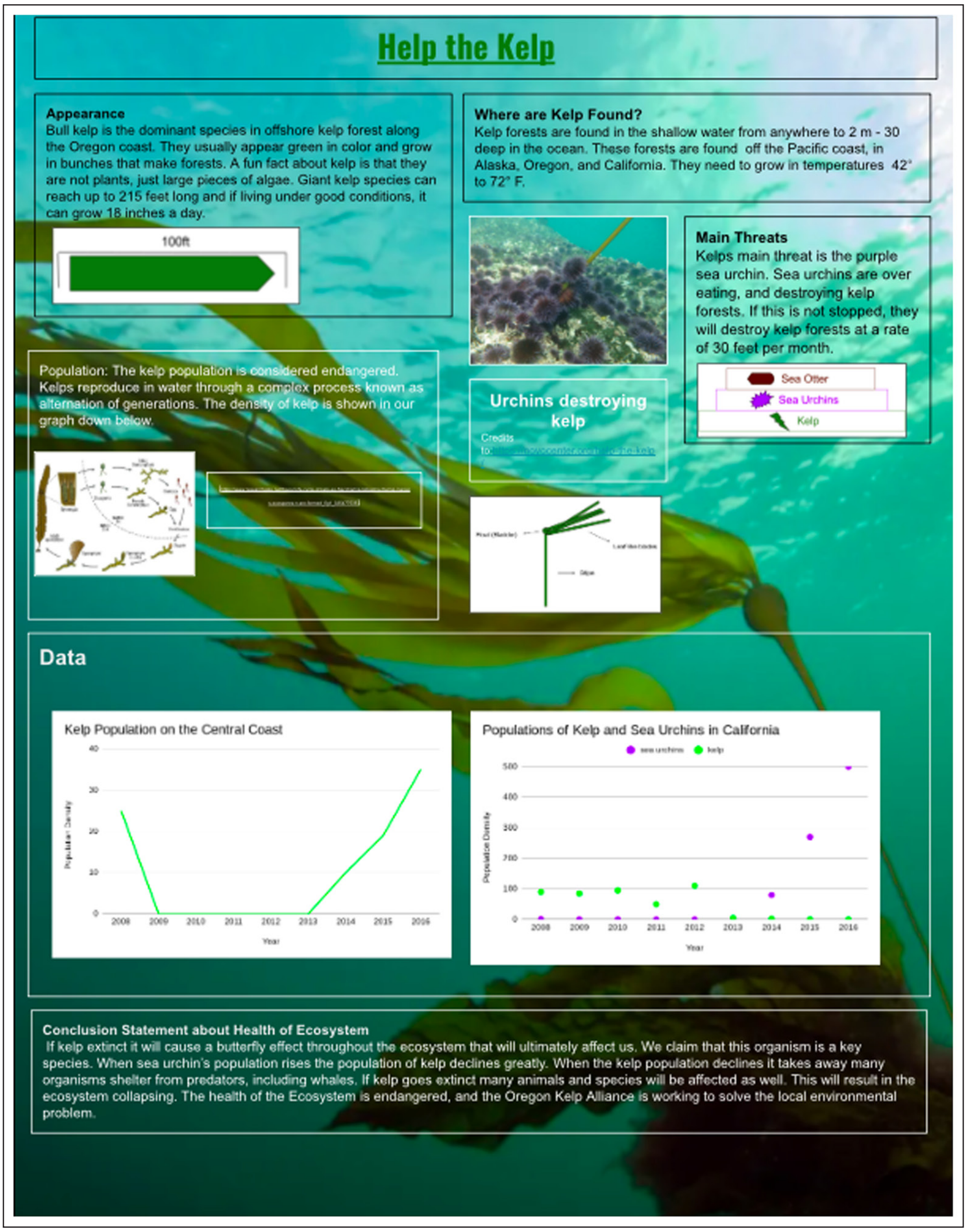
Sample student responses to the final task on the assessment.





APPENDIX D: ECOSYSTEM HEALTH HANDOUT

Student example



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COMPETING INTERESTS

The author has no competing interests to declare.

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