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# A Whale of a Roller Coaster

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## SCIENTIFIC RESEARCH TO CLASSROOM

Funded by the National Science Foundation, Polar-ICE partnered with the Monterey Bay Aquarium Research Institute's EARTH program to offer a collaborative workshop for educators and polar scientists to develop lesson plans that integrate polar data into the classroom curriculum. In this article, we share one of the many lessons created in this workshop.

*A Whale of a Roller Coaster* is a lesson that utilizes Drs. Ari Friedlaender, David Johnston, Doug Nowacek, and Andy Read's research on whales in Antarctica. Specifically, their cetacean research is part of the Palmer Long-term Ecological Research (LTER) program. The location of the Palmer LTER research station affords scientists the opportunity to study a polar marine biome with research focused on the Antarctic pelagic marine ecosystem, including sea ice habitats, regional oceanography, and polar food webs (Figure 1).

During the 20th century, over 2 million whales were harvested in the Southern Ocean as part of the commercial whaling enterprise. Cetaceans are a critical component of the Antarctic marine ecosystem. Therefore, scientists are interested in understanding the life history, population structure, and foraging ecology of these krill predators as they recover from near extinction.

The Polar Regions are experiencing the effects of climate change at a much faster rate than the rest of the planet, so understanding the behaviors of these creatures sooner rather than later is crucial. Through a combination of visual surveys, photographic identification, skin and blubber biopsy sampling, long-term satellite-linked tagging, and short-term multi-sensor behavioral tags, scientists strive to understand the recovery of these ocean giants and their ecological role in a changing environment. In combination with other research taking place at Palmer LTER, the scientists are studying how changes in the physical and biological environment affect the distribution and behavior of baleen whales.

## GOALS AND OBJECTIVES

In this lesson, students explore the use of motion-sensing tagging technologies utilized with Humpback whales around Antarctica. Students ask questions, interpret data, and develop models to gain an understanding of how technology can assist scientists in their study of ocean life. This lesson allows students to work with a unique data set that will instill a curiosity for learning more about how we study our oceans. Although this lesson focuses on Humpback whales in Antarctica, it could be used as a phenomenon in teaching about food webs, technologies used to study the environment, or as an engaging way to include data into any lesson.


FIGURE 1. Palmer Station on the West Antarctic Peninsula. Courtesy of https://commons.wikimedia.org

## LESSON DESIGN

The lesson is written for middle school students but is easily adapted for students above or below this grade level. The lesson uses the 5-E planning format which is a constructivist approach that leads the student through 5 stages of learning; Engage, Explore, Explain, Elaborate, and Evaluate. This format for lesson planning also allows freedom for differentiation for the teacher. Topics can be explored in little or great detail depending on their needs. The lesson is designed so teachers can have all the background information, videos, rubrics, presentations, exemplars, and documents that are

needed to conduct the lesson readily accessible to them on the MBARI EARTH website (link contained in resources).

## ENGAGE

How do scientists visualize what whales do during the 95% of the time they are below the surface of the water and out of sight? They use multi-sensor tags to record whales as they dive, eat, and socialize in the ocean. In the Engage portion of the lesson, students are asked to view a short video that animates the movement of a tagged whale. Students should watch the video without comments or questions at this time.

The animation shows the whale's path as a ribbon. The twists and turns in the ribbon directly relate to changes in the whale's orientation and motion as it moves through the water. By animating the whale's path and orientation into a three-dimensional continuous ribbon, behaviors can be visualized and conclusions can be drawn from the patterns that become visible.

Show the video a second time and ask students to make observations and ask questions. Prompt the students with questions such as: What do you think the whale is doing? What do the colors mean? Look all around the screen, what numbers do you see? What do you think they mean? Are there different shapes? What do you think they represent? Do you see certain maneuvers repeated? Figure 2 gives some of the observations that students may make.

Have students 'Turn and Talk' with their neighbor to compare observations and questions they came up with while watching the video. Conduct a whole class discussion to address the student's observations and questions.

## EXPLORE

After observing the ribbon model video, the students are then asked, "What kind of data would the whale tag need to gather to produce this video?" Student responses will vary but guide the discussion to include direction, depth (ascent/descent), body position of the whale (lateral roll), and speed/acceleration. In order to illustrate how scientists might use this data to get a picture of whale behavior, have the students look at the Polar-ICE data story (Figure 3). The figure shows whale movements over the course of a day, so discuss this graph with the students and have them look for patterns and ask questions.

## EXPLAIN

Using wired florist ribbon or adding machine paper, students should create a fictious ribbon graph for a whale. The ribbon model should incorporate ascents, descents, lateral rolls, and should show the whale surfacing to take a breath. Students should create their ribbon graph by tapping the material to the edge of a table or desk (Figure 4). Depending on the space available, it can vary in length.

Materials needed for each group:

- Wired florist ribbon or adding machine paper (50cm)
- One piece each of graphing paper, lined paper, and plain paper
- Tape
- Ruler

When the model is complete, ask students to describe their model. A small toy whale can help students physically move the 'animal' through their ribbon model, while they interpret the whale's movements. The students should write out their descriptions. A student's interpretation of the whale's movement may be similar to this; "The whale is descending, makes a lateral roll to the left, ascends a bit, lateral rolls to the right, ascends to the surface to breath…"

Using graph paper, the students should translate their three-dimensional ribbon graph to a paired down version that mimics the whale track data example (Figure 3). This graph will only show the depth changes of the whale over time, lateral rolls and body position of the whale is not included in this type of graph.

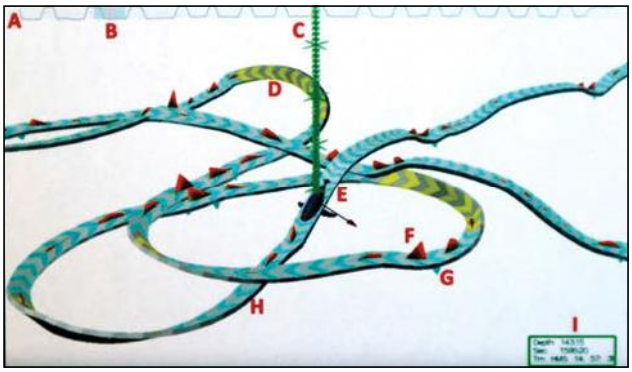


**FIGURE 2.** Use this screenshot from the video to help guide your discussions. A: graph indicating the complete track of the whale; diving and surfacing; and B: the red line shows where (in the graph) the whale is located at that moment in time. C: the green line indicates depth; D: the yellow areas show where the whale completes a lateral roll either left or right; E: is the position of the whale with the arrow pointing north; F & G: shows the fluke (tail) movement of the whale above (red) and below (aqua) a parallel plane, the height of the triangle indicates the strength of the movement; H: shows an area where the whale is descending; and I: quantitative data for depth and time. Link to 3-minute ribbon video in resources.

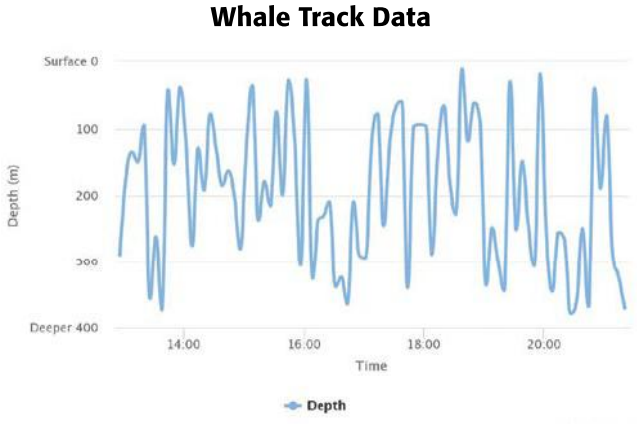


**FIGURE 3.** To better understand whale behavior, scientists use the data from whale tags to track the movements of whales below the surface of the ocean. Link to Whale Track Data in Polar-ICE Data Story in resources.

**FIGURE 4.** Example of a team's ribbon model using adding machine paper. The students remember to have the whale surface periodically to take a breath of air. Courtesy of Dr. Nancy FitzGerald

Collect the completed hand-drawn student graphs and the whale movement descriptions. Redistribute student graphs and their corresponding descriptions, making sure each group receives the graph of another group. This should be done secretly because the students are now going to try to match the graph they receive with the correct ribbon model.

*Grouping example:* if you have four groups, group 1 will receive the graph from group 2. Group 2 will receive graph from group 1. Group 3 will receive graph from group 4 and group 4 will receive the graph from group 3.

Direct students to match their anonymous graph with the ribbon models that were created. Once students feel that they have matched their graph with the correct ribbon model, they should use evidence and reasoning to back up their claims. Referring to depth changes and the written descriptions of the whale's movement would be common forms of evidence.

## ELABORATE

Students discuss why collecting and modeling data is important for understanding whale behavior and movement. Students are encouraged to discuss how an understanding of animals, their environment, and their behaviors can be used to guide conservation decisions, support policy, and help track changes in the environment.

In this case, the whale movement data can be linked to the movement of the whale's prey; krill. Use the Polar-ICE data story (link in resources) to elaborate on the relationship between the movement of the whales and krill. One key point that ties directly into this lesson is that the ribbon graphs allowed scientists to visualize the whale's movement and, in doing, they found that the whales tend to slightly roll their bodies to the side while feeding. A behavior that was unknown until this research was conducted.

## EVALUATE

Students should choose one of the following prompts to illustrate their understanding of how scientists use data and technology to monitor animal behavior. By giving students an open-ended way to show their knowledge, students interact with empirical data in a way that allows them to make connections and develop a true sense of how data could translate into environmental management.

A. **Making the Invisible Visible** (discuss how technology helps scientists monitor animals in ways that were never possible before, and why this is important to protecting and preserving species and/or ecosystems)
B. **The Web of Life** (discuss how interactions between organisms in the Antarctic ecosystem could be studied using similar technologies and data sets)
C. **It Takes a Village** (protecting an ecosystem or a species cannot be done in isolation, discuss the different areas of science and technology that were used in this example and how this can help us gain a better understanding of the Antarctic ecosystem)

## CONCLUSION

Tying together scientific data with a unique hands-on activity is the strength of this lesson as well as allowing for differentiation for a variety of grade levels and abilities. The authors have used the lesson, or portions of it, with elementary, middle school, high school, and college students. The lesson has also been the focus of numerous educator workshops. Data from

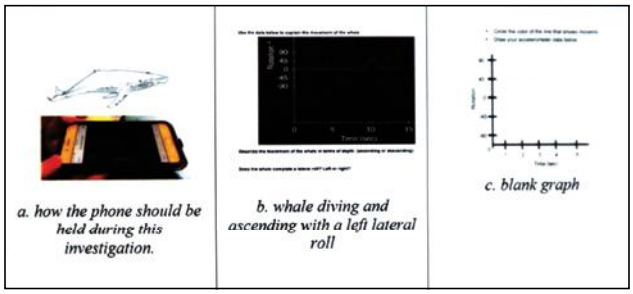


**FIGURE 5.** Students use an app called Sensor Kinetics to generate their own data. Whale drawing in Panel A courtesy of Joanna Chierici. Pictures in Panel A and B courtesy of Sensor Kinetics (photos and screenshots courtesy of Joanna Chierici). Blank graph in Panel C courtesy of Sensor Kinetics Worksheet from EARTH Lesson Plan

the classroom setting has yielded positive reviews. Feedback from educators that have participated in EARTH workshops designated the lesson as "adaptable" with a note that it can be easily incorporated into a variety of topics and standards across grade levels. This data was obtained in a feedback rubric developed by the host of the EARTH website. Anecdotal data and feedback from teacher workshops both at the local and regional level have yielded the following comments; 'engaging,' 'I didn't know data such as this existed,' 'I can't wait to use this in my classroom,' '(the lesson) provided hands-on activities related to the NGSS standards,' 'The information could be used across content areas, and help all levels of learners,' 'Great ideas that are easy to incorporate,' and 'The uniqueness of this data is really going to excite many students.' These comments are representative themes of feedback from all the workshops conducted. This data was obtained in post workshop surveys conducted by the presenter and by the administrative hosts of the workshops.

Furthermore, this lesson was developed in conjunction with the Polar-ICE project. Independent evaluation of the Polar-ICE project reveals that teachers and students participating in Polar-ICE workshops and activities have not only gained access to polar data and scientists, they have developed skills to analyze real-world scientific data and applied the data to their own scientific investigations. Students engaging in these authentic experiences identified positively to potential STEM careers and reported feeling more confident using data at the end of the experience. Educators participating in the workshops and activities improved their skills as to how to use real-world data in their classrooms. Educators noted the increased ability of their students to develop and ask scientific questions. Educators also noted students were interested to learn more about Antarctica from the smallest microbes to the largest whales.

## EXTENSION

As a technology extension, students are encouraged to use the mobile phone app "Sensor Kinetics" (available free of charge through Google Play and iTunes) to mimic the multi-sensor tag that scientists use to track and describe whale movement under the water. In this part of the lesson, the student's phone represents the humpback whale (Figure 5). The 'home button' of the phone is the front of the whale. The app captures data from the phone's accelerometer and gyroscope, so students are able to replicate the movement of a whale. Students describe the movement of the whale in terms of depth (ascending or descending) and lateral rolls (left or right). Teacher directions for using the app can be found on the MBARI EARTH website (https://www.mbari.org/a-whale-of-a-roller-coaster/).

## RESOURCES

- Whale of a Rollercoaster resources and EARTH lesson plan including the *Whale Track Video*: https://www.mbari.org/a-whale-of-a-roller-coaster/
  Access:
  - > Lesson Plan Part 2 Using Sensor Kinetics app with students
  - > Teacher Sensor-Kinetics Basics of using the app
- Link to 3-minute video used in the Engage section: https://drive.google.com/file/d/0BzDgvgELalc-LUxIejdxR0ZyRGM/view
- Dr. Ari Friedlaender - Link to current research: https://btbel.pbsci.ucsc.edu/
- Polar-ICE Data Story on *What are those whales doing?*: https://polar-ice.org/focus-areas/polar-data-stories/

## REFERENCES

Additional articles, and references and abstracts for all contributions are available on Polar-ICE (https://polar-ice.org/nmea_current/) and NMEA (https://www.marine-ed.org/s/Polar-Ice-Resources-Current.pdf) sites.

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