SEAFLOOR MAPPING | EDUCATOR

Links to Next Generations Science Standards |

MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

MS-ESS2-3: Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

MS-ESS3-1: Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.

MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

S T E M

Supplement Video |
https://www.youtube.com/watch?v=rEPXuXf0_Ws
https://vimeo.com/153100152 (password: exploration)

Pacing | 2 - 3 class periods (45 minutes each)

Background Needed | Basic understanding of sound, waves, earth history, earth processes, sonar

Assessment | Scientific & Technical Reporting rubric provided

Materials/Resources |

- Simulated seafloor boxes
- Low Resolution Grid (http://nautl.us/2eg1p5V) and High Resolution Grid (http://nautl.us/2dKZ7IN)
- Wooden dowels
- Student data sheets
- Colored pencils
- Calculators
- Computers with Microsoft Excel (optional)

Overview

This module is designed to introduce students to multibeam sonar mapping. Students will use simulated sonar beams to produce depth data on a seafloor. They will then take this data and produce a bathymetric map. Students will be asked to infer seafloor features based on two resolutions (low and high) of sonar imagery. Bathymetric maps can be produced by hand or students can easily use Excel to produce 3D bathymetric images.

Objectives & Learning Outcomes

- Students will be able to explain the importance of seafloor mapping to understand the earth and ocean as well as understand how little of the global ocean has been mapped (<10%).
- Students will understand how sound moves through water.
- Students will be able to calculate the depth based on time of sound return.
- Students will be able to produce bathymetric maps based on depth data.

Guiding Questions

- Why is it important to map the seafloor?
- How much of the global ocean has been explored?
- How does sound travel through water?
- How is sound used to locate objects?
- How do scientists benefit from detailed (high resolution) maps of the seafloor?

Links to Common Core Standards |

CCSS.ELA-LITERACY.RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-LITERACY.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Extensions & Adaptations

Introductory |
Students can be given all of the equations and provided with methods for calculating water depth using the equations of the speed of sound in water and various salinities of water.

Use color coded dowels for younger students to create their maps with. Students can create 3D interpretations of their maps with modeling clay.

Activity/Tasks

Students will:

- collect simulated sonar soundings for an unknown seafloor model.
- calculate the depth of their sonar soundings based on the speed of sound through water.
- infer what the seafloor features are based on the depth profiles created.
- compare and analyze the differences between their produced maps and the simulated seafloor.

Educator: Lesson Procedure/Directions

1. Introduction
    - Introduce students to the use of multibeam sonar mapping using resources available on www.nautiluslive.org (Our Technology & Video: Mapping Technology)
    - Introduce the ideas of sonar, seafloor mapping, and ocean exploration.
    - Direct students to begin mapping their seafloors according to the directions provided on the student worksheets.
2. Mapping Exercise Round 1
    - Students will use the “low resolution” grid to map their seafloors and see what features they can infer exist.
    - Students will then calculate ocean depths based on their sonar time data and produce a low resolution bathymetric map of the seafloor.
3. Mapping Exercise Round 2
    - Students will use the “high resolution” grid to map their seafloors and see what features they can infer exist.
    - Students will then calculate ocean depths based on their sonar time data and produce a high resolution bathymetric map of the seafloor.
4. Discussion
    - Ask students to share out their results comparing the low vs high resolution maps they have produced. Can students predict what type of seafloor structures they mapped? Ask students how their maps relate to multibeam sonar technology.
    - After this discussion and the final maps have been produced, instruct students to open their simulated seafloor boxes. Ask students to compare their results with the real seafloors. This is a great discussion point about the need for additional layers of deep-sea exploration beyond seafloor mapping (e.g., exploration with submersibles and visual imaging systems).

Pre-Lab Questions |

1. Who owns the ocean?
   - ✓ **Possible answers:** Out to 200 nautical miles, individual countries own the waters off of their coastlines for resource extraction (minerals or fishing), environmental policies, and navigation policies. This zone is called the exclusive economic zone or EEZ. Beyond the 200 mile barrier - also known as international waters - they are not owned by any country. This area is governed by international maritime law which must be built by international consensus and committee.

2. Where do the maps of our oceans come from? Why is it important to have good maps of the oceans?
   - ✓ **Possible answers:** Maps of the ocean can come from many technologies- geospatial satellites take hundreds of thousands of measurements of the sea surface averaging out wave heights and making maps of the microgravity anomalies that match seafloor terrain. The gravitational attraction of water to the mass of an underwater mountain actually causes additional water to be drawn to the feature resulting in a slightly higher ocean height over that spot. This microgravity map of the seafloor from a satellite is the type of large-scale, low-definition ocean imagery featured on Google Earth or Google Maps. Hull mounted multi beam systems collect far higher resolution maps, but the pace of data collection is far slower as a ship must transit over each feature to map it. Understanding ocean features determines regional and global ocean mixing and can define many of the biological environments know. Highly detailed maps are important for underwater navigation as well including military use for submarines. Scientists also need precise navigation data if they plan to return to specific sites over time.

3. How much of Earth's oceans have been mapped?
   - ✓ **Possible answers:** Only about 10% of the ocean has been mapped in high-resolution using hull-mounted (ship-mounted) multibeam sonar. All of the ocean's surface has been mapped by satellites.

4. Why are the oceans important to life on earth?
   - ✓ **Possible answers:** The oceans dictate the global climate and provide at least half of the oxygen in the atmosphere from phytoplankton productivity. The oceans are also the source of food for over 600 million people.

5. How does sound travel through water? How is sound used to locate objects?
   - ✓ **Possible answers:** Sound travels in waves and transmits well through dense saltwater. In fact, sound travels farther in water than in air. Sound waves are used to locate objects in water by timing the echoes of sound waves as they return from striking a target. Thus, sound is best used to locate hard objects (rocky seafloor, metal shipwrecks) because they give strong echo returns.

Extensions & Adaptations

Advanced |

Students can be tasked to find the equation for sound speed velocity and also told to determine a specific sound speed given specific parameters or average salinity of a particular body of water.

3D Mapping Using Excel |

If students have access to computers and Microsoft Excel, they can follow the instructions on how to produce a bathymetric map and visualization of individual 'sonar pings'. Students can also use Excel to produce a bathymetric map that they then print out and use as a template for cutting out foam layers to build their own 3D models of their seafloor. This activity can be done prior to opening the simulated seafloor boxes to allow students to make comparisons for accuracy. Refer to this link for example.

Extensions & Adaptations

Cardstock 3D Map | See PDF Shoebox Sonar for instructions on turning the data into a 3D Map made out of yardstick or foam.

3D Seafloor | If students have access to a 3D printer, data from the Excel-produced bathymetric maps can be used to print model seafloors.

Instructional Notes & Extension Ideas

Student: Lesson Procedure/Directions

1. Read worksheet introduction and follow directions to begin mapping your seafloor using the low-resolution template.
2. Calculate ocean depths by converting sonar ping time into ocean depth in meters using the equation provided.
3. After completing Round 1 of mapping, discuss with your group what type of features you think exist on your seafloor.
4. Map your seafloor again using the high-resolution template.
5. Calculate ocean depths again by converting sonar ping time into ocean depth in meters using the same method as before.
6. Color code the different depth zones in your data table.
7. Draw in contour lines over your data table. (Optional) Follow the directions on your worksheet to input your data into Microsoft Excel to create bathymetric maps.
8. Complete the analysis questions.

Seafloor Mapping | Educator Build Guide

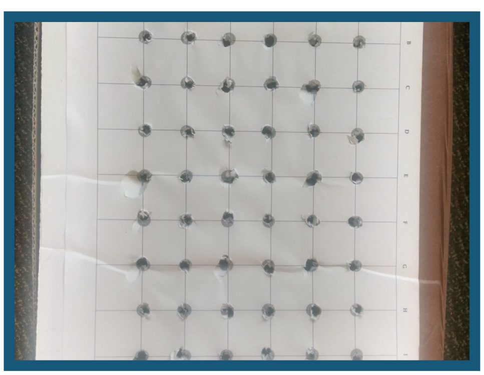
This guide will direct you on how to construct simulated seafloor boxes for students to use during this sonar mapping activity. You will need the following materials:

- Box with matching lid (shoeboxes, printer paper boxes or small cardboard boxes work well)
- Cardboard or foam piece which is equal in size to the top of your box
- Wooden dowel or other measuring 'stick'
    - This will need to be long enough to reach the bottom of your box with enough extra to hold onto
    - Diameter of drill bit should be slightly larger than dowel
- Suggested seafloor materials to provide a contoured surface for the bottom of your box:
    - Clay
    - Foam insulation
    - crumpled paper, recycled cans, bottles, plastic cups
    - scrap cardboard
    - Glue
    - Sharpies
    - Ruler
    - Tape

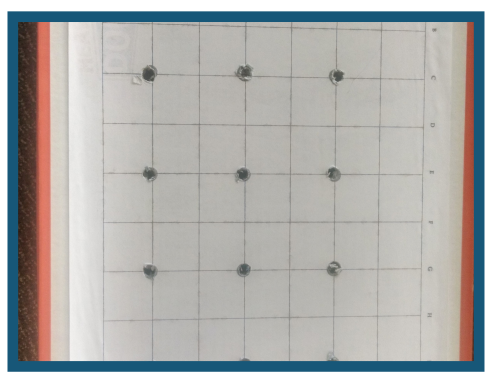
Procedure:

1. In the bottom of your box assemble the seafloor material to represent simple shapes of realistic seafloor features. Refer to following link for example: seafloor features. Possible configurations could be a seamount with the peak just below the surface, a valley with two steep slopes on either side of the box, a sloped plane moving from one side of the box to the other or any other seafloor feature.
2. Secure the seafloor the bottom of your box.
3. Cut cardboard to same size as box opening.
4. Print out the box lid templates scaled to fit your box size and cardboard/foam pieces.
5. Attach the 15 box low resolution template to the lid of your box. Refer to link: low resolution survey template.
6. Attach the 60 box high resolution template to the piece of cardboard/foam. Refer to link: high resolution survey template.
7. Drill holes using a drill bit slightly larger than your dowel, i.e. if your dowel is ½" then use a ⅝" drill bit to punch out. Drill each lid separately.
8. Use a piece of tape to secure the high resolution lid to the box.
9. Place the low resolution lid over the high resolution lid so they are aligned and send a dowel through each hole to make sure they are aligned and pathway is clear.
10. Build a simulated sonar ping dowel:
    1. Measure every half inch on the wooden dowel and mark it with a sharpie.
    2. Label the marks .5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0 etc. with the lowest number near the bottom (holding the dowel vertically). These marks represent the range of times a ping could take to travel ship-to-seafloor-to-ship.

Sample Seafloor Boxes



High Resolution Grid



Low Resolution Grid

SEAFLOOR MAPPING | STUDENT

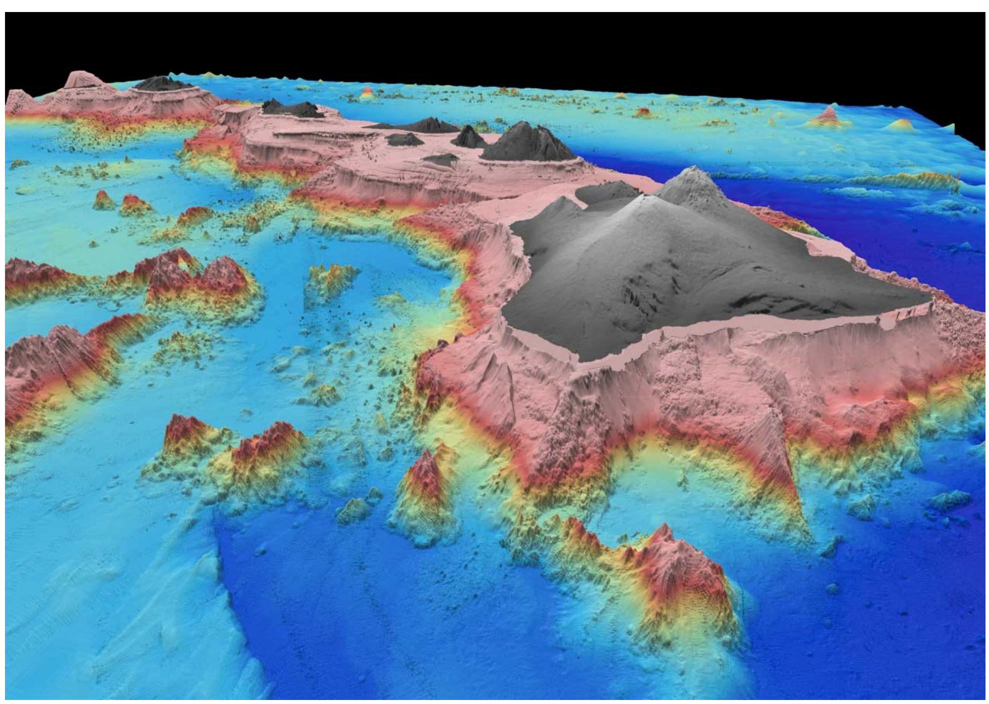
Learning Goals

- Explain the importance of seafloor mapping to understand the earth and ocean.
- Understand what percentage of the global ocean has been mapped.
- Understand how sound moves through water.
- Calculate seafloor depth based on time of sound return.
- Produce bathymetric maps based on depth data.

Introduction | Did you know more than fifty percent of the United States of America is found underwater? The exclusive economic zone of a country extends 200 nautical miles from the coastline encompassing the water and continental shelf seafloor below. This land is full of critical minerals, habitats and resources. As you can see in the image of Hawaii below, the amount of land we often think of as being part of the US is tiny compared to all that exists below the surface of the sea.

Much like Lewis and Clark did long ago, you have been tasked by the US Government to map part of the unexplored land belonging to the US. You will use a sonar mapping system to reveal your seafloor and understand what geologic features, man-made objects and other items of scientific interest exist in the area. Currently scientists have mapped less than ten percent of Earth's oceans! We have better maps of Mars and the moon than we do of our own planet's seafloor. The Nautilus Exploration Program uses a highly sophisticated multi-beam sonar system to produce detailed maps of the seafloor in areas we explore. These maps allow the Corps of Exploration to better select dive targets and reduce ROV navigation hazards. Maps are also shared with the public so others can return to the sites we explore to better understand the discoveries we make.

Challenge | Your challenge during this lesson is to map an unknown section of seafloor using a simulated sonar beam.



Perspective bathymetric image of the Big Island of Hawaii (© Hawaii Mapping Research Group)

SEAFLOOR MAPPING | STUDENT

Helpful Resources:

- Article: Corps of Exploration creates the first high-resolution maps of the Mesoamerican Barrier Reef in Belize http://nautl.us/25luBsD
- Article: Nautilus Tech- Understanding the tools of ocean exploration http://nautl.us/1RvtI6X

Pre-Lab Questions |

1. Who owns the ocean?

2. Where do the maps of our oceans come from? Why is it important to have good maps of the oceans?

3. How much of Earth's oceans have been mapped?

4. Why are the oceans important to life on earth?

5. How does sound travel through water? How is sound used to locate objects?

DON'T MISS PLAYLIST

Want to learn more? Check out these video clips from Nautilus Live!

Video: Behind the Science: Ocean geology in the Puerto Rico Trench
http://nautl.us/1Vl5006

Video: Interview with Larry Mayer, Chief Scientist of the expedition to Eratosthenes Seamount in Cyrus
http://nautl.us/27UPMUr

Materials |

- Seafloor mapping box
- Sonar ping dowel
- Colored pencils or crayons

Procedure |

Sonar pings or acoustic pulses are sound waves sent from a transducer toward the seafloor to detect distances. Acoustic waves bounce off hard surfaces, similar to an echo, and a computer onboard E/V *Nautilus* listens for the pulses to return. Knowing the speed sound travels through water, explorers can calculate seafloor depth within a survey by measuring the time elapsed before pulses return. In this mission, the dowel will represent an acoustic 'ping'. On your wooden dowel, each marked inch represents 0.5 seconds.

1. Read the worksheet introduction and follow directions to begin mapping your seafloor box using the low resolution survey lid.
2. Gently insert the dowel vertically into each grid hole until it hits bottom. Record the time from the dowel and complete TABLE 1. The dowel time represents the ship-to-seafloor-to-ship travel for the sound pulse.
3. Calculate ocean depths for each ping by converting time (seconds) into depth (meters) using the equation provided. Complete TABLE 2 with your calculations.
4. Once you have completed the low resolution survey, discuss with your group members what type of features you think exist on your seafloor.
5. Remove the low resolution survey lid to reveal the high resolution survey lid. Complete a high resolution survey of your seafloor using the same technique. Record your data in TABLE 3.
6. Calculate ocean depths for each ping in your high resolution dataset using the same calculations from step 3. Complete TABLE 4 with your results.
7. Create your own Bathymetry Color Key (p. 7) according to the depths of your mapping box.
8. Transform your mapping data into color-coded bathymetric maps by shading the different squares in TABLE 2 and TABLE 4 according to your key.
9. When your maps are complete, open the seafloor box to reveal the accuracy of your mapping.

Low Resolution Survey

• TABLE 1 and TABLE 2 show the grid of the 15-hole low resolution survey lid. Systematically survey the seafloor recording acoustic ping return time for each grid point in TABLE 1.

TABLE 1: Acoustic Ping Return Time (seconds)

	A	C	E	G	I
2					
4					
6					

• Use your data from TABLE 1 and the equation: Speed = Distance ÷ Time to calculate the total distance traveled for each acoustic ping.

- Assume sound travels through saltwater at 1500 meters per second.
- NOTE: The time data you recorded is the time elapsed as a sound wave travels to the seafloor AND returns to the ship's transducer. The total distance traveled needs to be divided by 2 to get the ocean depth from each ping.

• Use the information provided to complete TABLE 2.

TABLE 2: Seafloor Depth (meters)

	A	C	E	G	I
2					
4					
6					

High Resolution Survey

- Flip open the low resolution survey lid. Below it, you'll see a high resolution survey grid with 60 holes. Higher resolution surveys reveal greater detail of seafloor features. Follow the same procedure you used for the low resolution survey to record acoustic ping return time for each grid point in TABLE 3.

TABLE 3: Acoustic Ping Return Time (seconds)

	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										

- Use your TABLE 3 data and the equation, Speed = Distance ÷ Time to calculate the total distance traveled by each ping in meters. Remember to divide the total distance traveled in half to obtain the one-way travel, or seafloor depth, at the site of each ping. Record your seafloor depth data in TABLE 4.

TABLE 4: Seafloor Depth (meters)

	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										

Creating a Map |

1. Visualize your data by creating color-coded bathymetric maps. Color-coded bathymetric maps, like the map from Hawaii at the beginning of the exercise, make it easy to interpret large collections of sonar survey data.
2. Use colored pencils to color each square in TABLE 2 and TABLE 4 according to the corresponding color from your Bathymetry Color Key.
3. Topographic maps, commonly used in hiking, visualize terrain by marking contours or lines of equal elevation. Transform your seafloor color-coded maps (TABLE 2 and TABLE 4) into topographic maps by drawing depth contour lines through data points of equal depth.
4. When your maps are complete, discuss with your group members the types of features you see on your map. Open your seafloor box to reveal the true seafloor features.

Bathymetry Color Key - Create your own key representing the depths of your mapping box. For colors, it is helpful to stay within the same shades of color family (Ex: dark - light reds, oranges & blues). See an example key & map here: https://nautl.us/2tCRxI5

DEPTH (meters)	COLOR
Surface 0 -	

Student Analysis:
Compare your high and low resolution survey maps. How are they similar? How are they different? How closely did you reveal the true seafloor features? Look up some other bathymetric maps online. Compare and contrast your maps to the images found online. Provide two examples of why scientists are interested in using high resolution mapping technology to visualize the seafloor.

SEAFLOOR MAPPING | ASSESSMENT

Scientific & Technical Reporting Rubric

OBJECTIVE	**CRITERIA**			
	4 Exemplary	3 Commended	2 Emerging	1 Developing
Communication of Data and Analysis |	Student chooses appropriate formats (graphs, charts, tables, diagrams, etc.) to best communicate data. No errors in data format (includes titles, units, captions, etc.). Student provides a thorough and detailed written summary of data, including key observations, trends, and identification of outliers or anomalies.	Student chooses appropriate formats (graphs, charts, tables, diagrams, etc.) to best communicate data. Data may contain minor errors in format. Student provides a written summary of data, including key observations, trends, and identification of outliers or anomalies.	Student attempts to choose appropriate formats (graphs, charts, tables, diagrams, etc.) to best communicate data. Data may contain errors in format or may be missing some information. Student provides a weak written summary of data.	Student does not choose appropriate formats (graphs, charts, tables, diagrams, etc.) to best communicate data. Data may contain errors in format or may be missing some information. Student provides a minimal written summary of data.
Critical Thinking |	Student includes effective use of sources, facts and data to support what was learned in a conclusion or overview statement. Student is able to reflect on implications, errors and limitations of the data and connect to other topics. Student can suggest next steps or future improvements & modifications to topic(s) addressed.	Student uses sources, facts and data to support what was learned in a conclusion or overview statement. Student is able to reflect on implications, errors and/or limitations of the data. Student can suggest a next step or future improvement/ modification to topic(s) addressed.	Student uses some sources, facts or data to support what was learned in a conclusion or overview statement. Student is able to weakly reflect on implications, errors and/ or limitations of the data. Student attempts at suggesting a next step or future improvement/ modification to topic(s) addressed.	Student uses few sources, facts or data to support what was learned in a conclusion or overview statement. Student is able to weakly reflect on implications, errors and/ or limitations of the data.
Language and Conventions |	Student produces clear and coherent writing in which the development, organization and style are appropriate to task, purpose and audience. Demonstrates an exemplary command of standard English conventions.	Student produces writing in which the development, organization and style are appropriate to task, purpose and audience. Demonstrates a command of standard English conventions; errors do not interfere with understanding.	Student produces writing in which some development, organization and style are appropriate to task, purpose and audience. Demonstrates a limited and/or inconsistent command of standard English conventions; errors may interfere with understanding.	Student produces writing in which there is limited development, organization and style appropriate to task, purpose and audience. Demonstrates a weak and/or inconsistent command of standard English conventions; errors interfere with understanding.
Total Score | ________________	**Comments:**			

How Large is Nautilus Nation?

Tracking the reach of Ocean Exploration Trust's education programs is essential in ensuring we are funded to continue making discoveries and inspiring the next generation of explorers.

Name: **My Community (City, State):**

Email Address:

School's Name:

Instruction date: **Grade level instructed:**

Subject area:

My education space is a...

- ❏ Classroom
- ❏ After school program / Club meeting
- ❏ Fair / Festival / Event
- ❏ Museum / Science Center
- ❏ Other. Tell us more:

Who did you engage in your teaching?

Students

Community Members

Select all the OET materials you used in your instruction:

- ❏ STEM Learning Modules. Which ones? ______________________________
- ❏ Digital Resource Library materials. Which ones? ______________________________
- ❏ Nautilus Live website: photo albums ☐ highlight videos ☐ live stream
- ❏ Meet the Team STEM mentor profiles
- ❏ Facebook (NautilusLive) ☐ Twitter (@EVNautilus) ☐ Instagram (@nautiluslive)
- ❏ Other. Tell us more: ______________________________

____

What made working with OET resources valuable to your instruction (select all that apply)?

- ❏ Hands-on activities ☐ STEM career connections
- ❏ Easy to use lessons ☐ Standards-based lessons
- ❏ Website resource access ☐ Real world application of curricula topics
- ❏ Excitement of cutting-edge discoveries / Unfamiliarity of deep ocean
- ❏ Another reason. Tell us more: ______________________________

____

Using OET resources increased my confidence in teaching my science, technology, engineering, or math subjects.	☐ Yes	☐ No
OET provided me with helpful and relevant teaching resources.	☐ Yes	☐ No
Using OET resources increased my awareness of STEM careers.	☐ Yes	☐ No
If yes, how so? How can we improve?		

Please scan this document or snap a picture of it with your phone. Email the feedback or questions to education@oet.org. You can also submit feedback online: http://nautl.us/2cp3PNu

Thank You For All You Do!