NAVIGATION SIMULATION | 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-PS4-3: Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.

MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Links to Common Core Standards |

CCSS.ELA-LITERACY.WHST.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

CCSS.ELA-LITERACY.WHST.6-8.9: Draw evidence from informational texts to support analysis reflection, and research.

S T E M

Supplement Video |
https://www.youtube.com/watch?v=3aior3Xis1I
https://vimeo.com/172151005 (password: exploration)

Pacing | 1-2 class periods

Background Needed | Basic understanding of latitude and longitude, functionalities of GPS

Assessment | STEM Project & Task rubric provided

Materials/Resources |

- Class set of cones/markers to be used on a flat surface or outdoor area
- 1 blindfold per student group of 2
- Frisbees or plastic disks that can be used as ground place markers (2 different colored markers/group)
- Colored pencils
- Meter sticks, measuring wheels or measuring tapes (1 per group)
- Rulers

Overview

This learning module provides students the unique opportunity to learn about navigation in the deep sea through the use of a simulation. Students will complete two parts of the simulation, collect data and apply this to methods of tracking underwater vehicles. Upon completion of this module students should have a general understanding of how GPS works, why we use different methods of navigation under water, and the various tools, technology and careers associated with deep sea navigation.

Objectives & Learning Outcomes

- Students will be able to describe the challenges of underwater navigation.
- Students will understand the differences between dead reckoning and acoustic signaling as forms of underwater navigation.
- To collect and analyze data from a simulation and equate with important and challenging aspects of navigation.

Guiding Questions

- If you were going to leave your school and go to an address you had never visited before, how would you plan your route to get there? What tools would you want to use? How would this be different if you only had tools from 300 years ago?
  - ✓ **Possible answers:** we frequently use our phones, a GPS device or computers to type in directions and get a step-by-step route to where we are going. It would be much more difficult and time-consuming to navigate using tools from 300 years ago. Early tools could include use of a map, compass, position of sun and other known landmarks such as rivers.

Links to Common Core Standards |

CCSS.ELA-LITERACY.RST.6-8.9: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

CCSS.MATH.CONTENT.3.MD: Represent and interpret data.
CCSS.MATH.CONTENT.7.EE: Solve real-life and mathematical problems using numerical and algebraic expressions and equations.
CCSS.MATH.CONTENT.7.G: Draw, construct, and describe geometrical figures and describe the relationships between them.

Guiding Questions Continued

- Research and summarize how GPS works to guide you with directions. *Teacher tip: provide students with a selected list of websites or handouts that could aid them in their research.*
  - ✓ **Possible answers:** The Global Positioning System is a satellite-based navigation system consisting of a network of 24 satellites placed into orbit by the U.S. Department of Defense. The satellites send continuous radio signals to the planet's surface. Receivers such as in phones can pick up the satellites' signals and location can be determined based on the time it took the radio signal to travel from the satellite to the receiver. The receiver must pick up signals from a minimum of three satellites to determine a 2-D position (latitude and longitude). This happens through a process called triangulation.
- Why do ROV navigators need to rely on methods other than GPS?
  - ✓ **Possible answers:** The radio signals upon which GPS depends are not capable of passing through water.
- List several navigational tools used in deep sea exploration and describe their functions in underwater navigation.
  - ✓ **Possible answers:** SONAR, short for Sound Navigation and Ranging, is a system that emits sound pulses and measures their return after being reflected as a way to detect objects underwater and measure water depth. A transponder is a device that is capable of sending and receiving acoustic signals in order to provide a range and bearing to an object. Transponders are composed of two parts: a transceiver and a transducer. The transceiver receives the acoustic signal or ping and the transducer sends the signal out. Transponders on board the *Nautilus* and underwater vehicle *Hercules* communicate with each other to track position in the ocean depths.

Define the following terms:

Students will be able to understand and use the following vocabulary:

Acoustic signal/pings

- ✓ Sound waves which are generated by a transducer and picked up by a transceiver. Used to locate objects under water.

Bearing

- ✓ The direction as measured as an angle between the ship's forward direction and the location of the ROV.

Dead reckoning

- ✓ The process of calculating your current position by using a previous fix and advancing that position based upon known or estimated speeds over elapsed time and distance.

Set The Stage!

Get students thinking about the process of navigation by asking the following questions:

- How do we know where we are and why?
- Why do we trust that?
- If you have to go somewhere and don't know where it is how do you get there?
- How does a GPS work?
- In a perfect world, how many times would you like to ask for directions?

Use students' responses to these questions to lead a discussion about the technology used to navigate and find our way around the world, and how navigation methods have changed over time. It is important for students to understand that a phone has to "ask" the satellites where it is, it will not automatically know; navigation does not "stream" to the phone.

Fix

- ✓ Position derived from measuring external reference points.

GPS

- ✓ Global Positioning System that relies on 24 satellites orbiting Earth and sending radio signals to receivers on the surface. The location of a receiver picking up signals from a minimum of 3 satellites can be determined based on a process called triangulation.

Range

- ✓ The distance to an underwater vehicle as determined by the return data from a transponder; calculated based on the time for an acoustic signal to travel between a transducer and a transceiver.

Sampling frequency

- ✓ How often the transducer sends a ping to the transceiver to get an estimate of distance.

Sonar

- ✓ Sound navigation and ranging; a system that emits sound pulses and measures their return after being reflected as a way to detect objects underwater and measure water depth.

Transceiver

- ✓ A device that receives signals from a transducer.

Transducer

- ✓ A device that produces a signal picked up by a transceiver.

Transponder

- ✓ A device that contains both a transducer and a transceiver; used to provide range and bearing for underwater apparatus or vehicles.

Activity/Tasks

Students will:

- complete guiding questions and vocabulary to get better acquainted with navigation terminology and content.
- pair up and complete parts one and two of the simulation procedure, collecting data and documenting their trials.
- compare the simulation data to real world aspects of underwater navigation.
- reflect on their learning by completing analysis questions.

Extensions & Adaptations

Introductory |
Students can research navigation strategies utilized during a specific time period. Students can make a classroom timeline showing the progression of navigational tools and influential people through the years.

Advanced |
Refer to analysis question 5; ask students calculate the ideal ping rate based on depth, the speed of sound through water (1500 m/s) and the equation v (1500m/s) = d (depth in m)/t (time in s).
Ask students to calculate how often transponders should ping back and forth at a) 1000 m, b) 2500 m, and c) 4000 meters depth. Remind students to avoid overlapping signals, so they may want to round up time, and account for round-trip time, not just one way. Answers:
a) once every 2 seconds
b) once every 4 seconds
c) once every 6 seconds

Interdisciplinary |
Have students read the book *Longitude* by Dava Sobel (1995) to deepen their understanding of navigational history, notable inventors and tools.

Educator: Lesson Procedure/Directions

✓ **LESSON SET-UP |** It is suggested that students work in pairs to complete this module. It may be helpful to introduce the concepts of navigational history, latitude and longitude prior to the start of the lesson. Teachers may choose to have the cones set up prior to the activity or enlist the help of students to set up the cones when ready for the simulation.

☐ Helpful tips:

- ✓ Change the spacing between the cones and number of steps students can take based on grade level of students. Older, taller students can take more steps and walk further between the cones than younger ones.
- ✓ In the simulation first round, make sure students remain silent to avoid navigation clues (cheating).
- ✓ In the first round, students' navigation should be quite far off base. Keep a close eye for peeking or unapproved clues as the demonstration relies on increased accuracy with increased clues.
- ✓ After part 1 of the procedure, have students discuss (only with their partner) what worked, what didn't and how they could improve accuracy. Refer to the margin space of the student version for these questions.
- ✓ It is important for students to understand that when they were listening to the code word during the second part of the simulation, they were getting a "how far away" and "direction" of the target. This is similar to a transponder providing a range and bearing to the target.
- ✓ Use the analogy of playing Marco Polo to help students understand that acoustic navigation is based off transponders "yelling" or signaling to each other, one on the ship and one on the underwater vehicle.
- ✓ Inform students that transducers can be set to different frequencies so the transceiver is only picking up or "listening" to that frequency- this mimics the simulation's code word use with only their partner listening for that word.

Student Procedure

1. Determine student pairs.
2. Individually, complete guiding questions and vocabulary terms using online and module resources.
3. Complete parts one and two of simulation.
4. Complete associated worksheets.

Analysis Questions

1. Using your data plots, summarize your results for both the visual and acoustic navigation trials. Which set of trials yielded better results? What external factors may have played a role in your results?
   - ✓ **Possible answers:** Ideally, the acoustic trials with multiple samples (peeks and pings) would have more accuracy. If there was unintentional noise generated by the group during the trial, results may easily vary.
2. For trials 2 and 3 (visual) and trials 4 and 5 (acoustic), what was the connection between the location where you peeked (or where your partner said the code word) and having a more accurate location/fix on the target? If there was no connection, why not?
   - ✓ **Possible answers:** Again, results may vary. Theoretically, the closer a student was to their target when they peeked or pinged, the more accurate their fix should be. If a student was farther away, then it is less likely that their final fix was very accurate.
3. What techniques or tools might have made these trials more accurate, both visually and acoustically?
   - ✓ **Possible answers:** Pinging or peeking constantly would greatly improve the accuracy of the results. Additionally, students could measure their stride length before taking steps to estimate the distance they must walk to make it to the target cone and back again. Compasses may be introduced into the activity determine precise bearings. For added fun, hand out ear plugs and have each student plug one ear to see how that affects results.
4. Now imagine that you are a trying to accomplish a similar task but underwater. What additional challenges does the underwater environment add to this simulation that you didn't experience navigating between cones on land? Which style of navigation would be most effective over long distances and which style would be most effective over short distances? Explain your answer.
   - ✓ **Possible answers:** Aside from insufficient oxygen and pressure, deep water adds the challenge of blocking electromagnetic radiation. Radio doesn't work (no GPS) and light is absorbed or refracted within short distances. Sound navigation is effective over long distances because long wavelength energy travels very far at relatively high speeds. Light (vision) would then be used to hone in on a target once it was localized with sound.
5. Which part of the simulation represented bearing? Which represented range?
   - ✓ **Possible answers:** The angle between the student walking and his/her home base is the bearing. The distance traveled represents range.
6. During underwater exploration, which factors would affect how often you would want to send out pings? What would be ideal? What are the limitations?
   - ✓ **Possible answers:** The distance to the target would affect how often a student would want to ping. The farther away, the less frequent the ping. Ideally, the frequency of the pinging would increase as the student approached the target. One limitation might be that pinging over very long distances (an entire ball field) might be very hard to hear. Another might be that many groups of students pinging frequently would likely result in mixed signals.

NAVIGATION SIMULATION | STUDENT

Learning Goals

- Learn about the challenges associated with deep sea navigation and the technologies ROV pilots and scientists use to overcome these challenges.
- Understand the differences between dead reckoning and acoustic signaling as forms of underwater navigation.
- Complete a simulation to explore and describe differences between two methods of underwater navigation.

Introduction | How do you navigate the world around you and what tools do you use to help accomplish this? Which environments are more difficult to navigate through and why? In this lesson you will learn the concepts used to navigate robotic vehicles in the deep sea and how technology helps scientists, engineers and ship officers work at sea and on the seafloor.

Humans have been using boats for trade for more than 5500 years. Early wayfaring depended on careful observation of local landmarks, weather patterns, and constellation orientation. Many famous voyages of exploration— Magellan's circumnavigation, Columbus's charting of the Caribbean, Zheng He's Chinese armada, Polynesian Pacific colonization— were made with only basic tools for knowing where ships were headed. Technology advances of each historic era made navigation more precise and efficient. In the 1700s, the invention of the sextant, a hand-held metal instrument for measuring angles between stars and the horizon, enabled sailors to use math to pinpoint a ship's latitude (how far North or South of the equator it was located). The development of accurate and rugged clocks, called ship chronometers, and complex math regarding the curve of the Earth enabled sailors to pinpoint their ship's East/West position, or longitude. In the last century, technology like radio and satellites transformed the field of navigation. Modern ships, car navigation systems, and even smartphones rely on Global Positioning System (GPS) technology - a system of 24 high-orbit satellites circling Earth transmitting radio signals to receivers. On the Exploration Vessel Nautilus, a receiver secures signals from four satellites and calculates - triangulates - the ship's position based on the distance the signal traveled from each satellite. Technology makes this process continuous and instantaneous.

Navigation underwater is more complex as GPS signals can not penetrate the ocean surface. Remote Operated Vehicles (ROVs) must rely on different methods of tracking. In this module, you'll take the role of the underwater robot in investigating these technologies. **Learn more about these methods through this link: robot navigation in the deep sea.** (nautl.us/1WV85Wu)

Clara Smart, Corps of Exploration navigator, works with the ROV pilots to maneuver the ship and underwater vehicles for exploration.

Helpful Resources:

- [“Oceanographic Tools: Navigation by Sound”www.divediscover.whoi.edu/tools/navigation-sound.html]
- [“Oceanographic Tools: Satellite Navigation”www.divediscover.whoi.edu/tools/navigation-satellite.html]

Guiding Questions |

1. If you were going to leave your school and go to an address you had never visited before, how would you plan your route to get there? What tools would you want to use? How would this be different if you only had tools from 300 years ago?

2. Research and summarize how GPS works to guide you with directions.

3. Why do ROV navigators need to rely on methods other than GPS?

4. List several navigational tools used in deep sea exploration and describe their functions in underwater navigation.

SCIENTIST SPOTLIGHT

Clara Smart
Navigator, E/V Nautilus
Graduate Research Assistant/ PhD Student
University of Rhode Island

"As an engineer my job is to develop tools and processing techniques to help answer questions posted by scientists. I enjoy developing creative approaches which push engineering and science, making deep ocean discoveries possible. My most memorable moment of the 2015 California expedition was discovering and mapping the cold-seep at Redondo Knoll. This stunning, extensive active seep site was previously unknown, but so close to land we had cellphone service! The resulting high resolution images of this site are stunning and will provide the impetus for additional exploration and sampling in the area. My advice for STEM career seekers is to chase the project, not the job title. Look around you! What inspires you; what do you wish you had helped design? Learn as much as you can about the people- who worked on these projects, what did they study, how can you get there? When the going gets tough - and it will, remember that initial inspiration."

Vocabulary |

Acoustic signals/pings:

Bearing:

Dive target/way point:

Fix:

GPS:

Navigator:

Range:

Sampling frequency:

Sonar:

Transceiver:

Transducer:

Transmit frequency:

Transponder:

Triangulation:

Thoughts for Discussion…

As you conduct the visual navigation trials, think about the following and discuss with your partner before beginning acoustic navigation trials:

- What worked well in these trials? What improvements did your group make between the first and second student walker?
- What didn't work well/what was difficult?
- What could be done to improve this process?

Materials |

- 1 set of cones & 1 blindfold per student group
- Items to be used as place markers for each group such as frisbees or plastic disks. Each group should have two place markers of different colors.
- 3 different colored pencils per group
- 1 Meter stick/measuring wheel or measuring tape per group, rulers

Procedure |

Set Up:

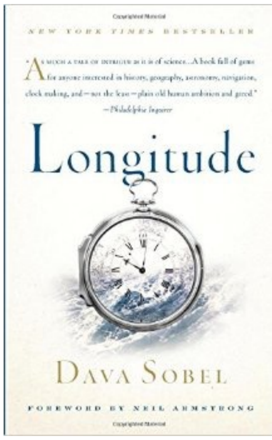
1. Pair up with a classmate. Select roles as Student A (SA) and Student B (SB). Each student chooses one place marker.
2. Arrange two parallel lines of cones. Each pair needs a home base cone, spaced 3-5 feet from other home bases. Parallel to the home base line is a target line. Your teacher will inform you how far apart the home base and target line cones need to be. Record this distance here: _________.

Visual Navigation:

Pair up with your partner on the home base cone. Everyone at the home base cone must remain silent as your teammate navigates.

3. **Trial 1- dead reckoning:** Blindfold Student A (SA). Ask SA to walk 15 normal steps towards the target cone with their place marker, stop, turn 180° and attempt to return 15 steps back to home base. SA drops their place marker on ground in final location.
4. Remove the blindfold. Switch roles. SB walks out toward target and back blindfolded, setting their place marker on ground in final location. Students record each other's locations (fixes) on the Visual Navigation Grid. Use a meter stick, measuring tape or measuring wheel to help mark an accurate location on the map. Choose one color to represent trial 1 locations or fixes, designating SA and SB on grid.
5. **Trial 2- course correction:** Repeat steps 3 and 4, however this trial each student can STOP, lift the blindfold, and peek at the path ONCE for 2 seconds. It is up to each group where on the path to remove the blindfold for the quick peek. Record two more positions on the Visual Navigation Grid in a different color.

Further Reading (A deeper dive)



Ready to learn more about the story of one of the greatest scientific breakthroughs of all time? Check out the book *Longitude* by Dava Sobel (1995) to read how the journey to accurately measure longitude transformed ocean navigation forever.

Procedure Continued |

6. **Visual Navigation Trial 3- double course correction:** This trial students can stop, lift the blindfold, and peek at the path TWICE along the way- once towards the target cone and once on the way back to home base. Again, it is up to each student where they want to peek. Repeat the process to record two more positions (SA fix and SB fix) on the Visual Navigation Grid using a third color.

Acoustic Navigation:

Your robots have been upgraded with an acoustic signaling system! Partners pick a code word to be your signal tone and then stand at opposing cones.

1. **Trial 1:** SA puts on blindfold and walks toward SB. Once along the path, SA can ask SB to say the code word. When SA thinks they have reached final location, SA drops the place marker on ground. Remove the blindfold, switch partner roles and repeat. Record final locations of SA and SB on the Acoustic Mapping Grid in one color.
2. **Trial 2**: Repeat step 1. During this trial you can request that your partner say the code word twice during your walk. You decide when to ask. Record final locations in a second color on the Acoustic Mapping Grid.
3. **Trial 3:** Repeat step 1 but now each of you can ask for the code word every 4 steps. Record final locations in a third color on the Acoustic Mapping Grid.
4. Complete the analysis questions.

On *Nautilus*, the navigator uses a variety of monitoring computers and an intercom system which links each role in the control van, the social lounge, the mess, the bridge, the data lab, and wet lab as well as the Inner Space Center at the University of Rhode Island.

Visual Navigation Grid

On the grid below, mark the location of the target and home base cones. Create a scale for this chart. Plot the final fixes from each trial in different colors (6 fixes, 3 trials), note which fix is SA and which is SB for each trial.

Acoustic Navigation Grid

On the grid below, mark the location of the target and home base cones. Create a scale for this chart. Plot the final fixes from each trial in different colors (6 fixes, 3 trials), note which fix is SA and which is SB for each trial.

Analysis Questions

1. Using your data plots, summarize your results for both the visual and acoustic navigation trials. Which set of trials yielded better results? What external factors may have played a role in your results?

2. For visual trials 2 and 3 and acoustic trials 1 and 2, what was the connection between the location where you peeked (or where your partner said the code word) and having a more accurate location/fix on the target? If there was no connection, why not?

3. What techniques or tools might have made these trials more accurate, both visually and acoustically?

4. Now imagine that you are trying to accomplish a similar task but underwater. What additional challenges does the underwater environment add to this simulation that you didn't experience navigating between cones on land? Which style of navigation would be most effective over long distances and which style would be most effective over short distances? Explain your answer.

5. Which part of the simulation represented bearing? Which represented range?

6. During underwater exploration which factors would affect how often you would want to send out pings? What would be ideal? What are the limitations?

NAVIGATION SIMULATION | ASSESSMENT

OBJECTIVE	CRITERIA			
	4 Exemplary	3 Commended	2 Emerging	1 Developing
Knowledge & Understanding |	Student consistently, correctly and thoroughly answers all questions. Uses an abundance of relevant vocabulary and is able to explain relationships within the content using examples. Can apply the content to other topics or real life.	Student is able to consistently answer most questions correctly. Uses an adequate amount of relevant vocabulary. Can explain relationships within the content and can apply content to other topics or real life.	Student is able to answer some questions correctly. Uses some relevant vocabulary. Student does not elaborate on relationships within the content or make connections between the content and real life.	Student is able to answer a few questions correctly. Inconsistently uses relevant vocabulary. Student does not elaborate on relationships within the content or make connections between the content and real life.
Content Organization, Methodology & Analysis |	Student effectively organizes complex ideas, concepts, and information to make important connections and distinctions. This may include detailed, labeled and thorough procedures, data tables, graphs, diagrams and/or analyses.	Student is able to organize ideas, concepts, and information to make connections and distinctions. This may include mostly detailed, labeled and thorough procedures, data tables, graphs, diagrams and/or analyses.	Student attempts to organize ideas, concepts and information to make some connections and distinctions. Student is able to provide basic procedures, data tables, graphs, diagrams and/or analyses.	Student has difficulty organizing ideas, concepts and information to make connections and distinctions. Student is unable to provide basic procedures, data tables, graphs, diagrams and/or analyses.
Self-Directed Learner |	Student is actively engaged in the learning process; consistently contributes to class discussions and asks clarifying questions. Seeks out and shares additional resources with the class or teacher. Advocates for his/her learning needs.	Student is engaged in the learning process. Often contributes to class discussions and asks clarifying questions. Advocates for his/her learning needs.	Student is inconsistently engaged in the learning process. Sometimes contributes to class discussions or asks clarifying questions. Inconsistently advocates for his/her learning needs.	Student is weakly engaged in the learning process. Rarely contributes to class discussions or asks clarifying questions. Rarely advocates for his/her learning needs.
Technological Tools |	Use of digital resources is always appropriate for the task. Willing to learn and use technology for inclusion of charts, graphs, pictures, etc. to amplify the message.	Use of digital resources is appropriate for the task. Willing to use technology for inclusion of charts, graphs, pictures, etc. to amplify the message.	Use of digital resources is sometimes appropriate for the task. Inconsistent use of technology for inclusion of charts, graphs, pictures, etc. to amplify the message.	Use of digital resources is rarely appropriate for the task. Inconsistent use of technology for inclusion of charts, graphs, pictures, etc. to amplify the message.
Collaboration Skills |	Consistently works effectively and respectfully with a diverse group of learners. Actively checks with others for understanding and how he or she may be of help. Student listens when others speak and incorporates or builds off of the ideas of others.	Works effectively and respectfully with a diverse group of learners. Checks with others for understanding and how he or she may be of help. Student listens when others speak.	Sometimes works effectively and respectfully with a diverse group of learners. Sometimes checks with others for understanding and how he or she may be of help. Student listens when others speak.	Has difficulty working effectively and respectfully with a diverse group of learners. Rarely checks with others for understanding and how he or she may be of help. Student may talk over other students or does not listen when others speak.
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
- ❑ Easy to use lessons
- ❑ Website resource access
- ☐ STEM career connections
- ☐ Standards-based lessons
- ☐ 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!