

Engineering to Explore the Ocean:

A Cooperative Educators Professional Development Workshop by the National Oceanic and Atmospheric Administration and the United States Naval Academy

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Abstract

Engineering to Explore the Ocean is a professional development workshop for K-16 teachers offered as a collaboration between the National Oceanic and Atmospheric Administration's Office of Ocean Exploration and Research Education Program (NOAA OER) and the United States Naval Academy's STEM Center for Education and Outreach (USNA STEM). NOAA OER's aim is to provide professional development for educators in the modern technology behind ocean exploration, which is complemented by USNA STEM's goal to expose teachers to hands-on, inquiry-based STEM education and project-based learning methodology. The partnership between NOAA OER and USNA STEM came in response to the Next Generation Science Standards (NGSS) emphasis on engineering design, earth systems, earth and human activity, and ecosystems in K-12 curriculum (NGSS Lead States, 2013) and a national need to recruit students into science and engineering undergraduate majors and careers (Committee on STEM Workforce Needs for the U.S. DOD, 2012; U.S. Department of Labor, 2007). Given that the ocean covers 71% of earth's surface and contains many unexplored resources and ecosystems, the workshop merges science application, science demonstration, and engineering design to explore oceanographic concepts and ocean engineering.

Introduction

According to the Next Generation Science Standards (NGSS), humans are driven by "a need to know and understand the world around them" (NGSS Lead States, 2013, Appendix H, p. 2). This drive is prompted by an underlying natural curiosity and the potential of a better life as a result of scientific discoveries. Similarly, engineering and technology complement science because they further accommodate human curiosity, needs, and objectives. With this in mind, both ocean exploration and ocean engineering support the NGSS. Ocean exploration "captures imaginations, intrigues young minds, has the potential to inspire an ocean science-literate citizenry and foster the innovative thinking that leads to engineering and technology literacy" (NOAA, 2012, p.vi). Ocean engineering applies scientific knowledge to design and develop ships, vehicles, and instruments for the marine environment, all of which are essential for ocean exploration. Therefore, NOAA OER and USNA STEM have partnered to provide ocean exploration and engineering professional development for educators.

NOAA's Office of Ocean Exploration and Research and the NOAA Ship *Okeanos Explorer*



As the only U.S. ship exclusively tasked to systematically investigate Earth's underexplored oceans, the NOAA Ship *Okeanos Explorer* (Figure 1) operates with the goal of discovery and subsequent knowledge advancement (NOAA, 2012). This mission is facilitated by an innovative strategy of systematic ocean exploration using multibeam SONAR, water column exploration, remotely operated vehicle (ROV) site characterization, and telepresence communication technology.

Multibeam SONAR. SONAR (SOund NAvigation and Ranging) technology uses the reflection (echo) of emitted sounds (pings) in the water to determine the depth of the sea floor. The device that generates the ping and receives the echo is called a transducer.

The *Okeanos Explorer* employs a more sophisticated technology called multibeam SONAR, which uses multiple transducers mounted at various angles on the ship's hull to generate a swath of depth sounding data (NOAA, 2012). This allows for higher resolution maps of the seafloor and improved detection of bathymetric features.

Figure 1. The NOAA Ship *Okeanos Explorer* is the only federally funded U.S. ship assigned to investigate Earth's underexplored oceans.

Image courtesy of NOAA Office of Ocean Exploration and Research (http://oceanexplorer.noaa.gov/okeanos/media/hires/ex_bow_starboard_side_hires.jpg).

Figure 2. A CTD rosette in which water-sampling bottles are arranged in a circle.

Image courtesy of NOAA Vents Program (http://oceanexplorer.noaa.gov/explorations/12fire/background/hires/ctd_closeup_hires.jpg).

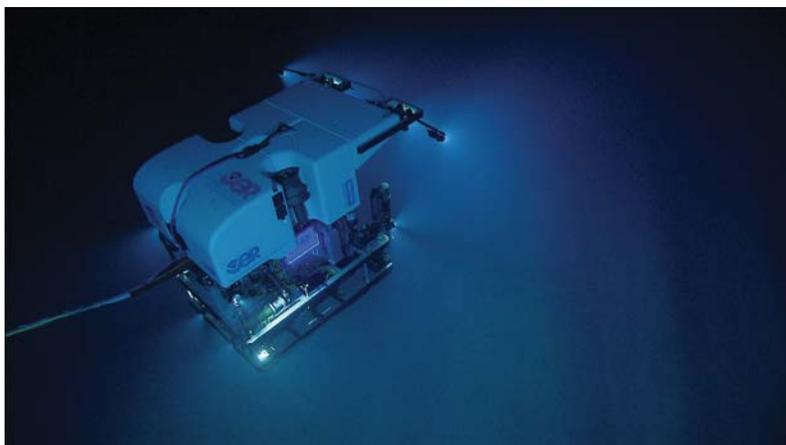
Figure 3. ROV *Deep Discoverer* during a dive in the Atlantic Ocean.

Image courtesy of NOAA Okeanos Explorer Program, Our Deepwater Backyard. Exploring Atlantic Canyons and Seamounts 2014 (<http://oceanexplorer.noaa.gov/okeanos/explorations/ex1404/dailyupdates/media/sept5-hires.jpg>).



Water column exploration. The vertical water column is further explored using a CTD instrument. CTD stands for conductivity, temperature, and depth and often refers to a CTD rosette (Figure 2) in which water-sampling bottles are attached to a frame in a circle and lowered into the ocean using a cable. The bottles are closed at different depths to sample and detect variations in the physical and chemical properties of seawater. Geologic activity within the seafloor can have significant effects on water chemistry through subsea volcanic eruptions and hydrothermal vent formation. As such, CTD measurements are useful for locating these features and their associated chemosynthetic communities (NOAA, 2012).

ROV site characterization. If anomalies are detected during either multibeam mapping or CTD water column exploration, scientists may deploy a remotely operated vehicle (ROV) for a more detailed site characterization. An ROV is an unmanned robot equipped with cameras, sensors, tools, and hydraulic arms that is connected via cable to and controlled by the surface ship. The *Okeanos Explorer's* ROV, *Deep Discoverer* (Figure 3), is uniquely tethered in series to a camera platform above in order to provide additional light and images of the ROV at work (NOAA, 2012).



Telepresence. Throughout this process of systematic ocean exploration, video and audio of the *Okeanos Explorer's* activities are transmitted remotely in real-time to scientists and the general public using an advanced satellite communication technology called telepresence (NOAA, 2012). Telepresence enables scientists on shore to participate in the discovery dialogue, thereby enhancing the pace, scope and capacity of ocean exploration. Telepresence technology also allows students and educators worldwide to witness ocean exploration as it unfolds via the internet.

The United States Naval Academy STEM Center and SeaPerch

SeaPerch is a national program sponsored by the Office of Naval Research (ONR) and managed by the Association for Unmanned Vehicle Systems International (AUVSI) which provides an exciting way to explore the subsea world and an introduction to science and engineering career opportunities. The USNA STEM Center trains teachers nationwide on how to design and build an educational ROV called a SeaPerch, how to incorporate hands-on methodology in their classrooms, and how to start a SeaPerch club at their school.

Although USNA STEM's SeaPerch Program and NOAA's OER Education Program are two separate informal education programs, their missions are complementary. NOAA's OER Education Program focuses on improving ocean literacy for learners of all ages, engaging educators and students in ocean exploration, connecting teachers to ocean explorers using innovative technology, and providing learning and teaching tools focused on the science of ocean exploration (NOAA, 2015a).

USNA STEM's mission is to address an urgent national need for more young people to pursue careers in science and engineering, to demonstrate a hands-on STEM education and Navy-relevant project-based learning, and to capitalize on unique resources that make STEM come alive for K-16 students (USNA, 2015). Both USNA STEM and NOAA OER strive to serve educators using innovative methodology and real-world science applications.

Focus of Workshop

The *Engineering to Explore the Ocean* workshop is a day and a half event that merges the NOAA Ship *Okeanos Explorer* Education Materials Collection, Volume 2: *How Do We Explore?* (NOAA, 2012) program with USNA STEM's hands-on STEM modules and SeaPerch ROV build (Figure 4). The workshop focuses on facilitating the underwater experience, capturing and analyzing ocean data, advances in ocean exploration technology, and the engineering design process. USNA STEM and NOAA OER facilitators work to "bring the ocean" to participants and ultimately into their classrooms with experiential learning.

Data collection, model development, and data analysis are emphasized in the workshop. During the *Wet Maps* lesson (Figure 5), depth sounding data is collected using everyday materials (pencils as sounding rods, shoe boxes as model oceans, Styrofoam shapes representing seafloor features). The data collected is then plotted on charts, and three dimensional models of each "seafloor" are constructed. A higher-tech version

To access NOAA Ship *Okeanos Explorer* Education Materials Collection, Volume 1: *Why Do We Explore?*, visit: <http://oceanexplorer.noaa.gov/okeanos/edu/collection/wdwe.html>

To access NOAA Ship *Okeanos Explorer* Education Materials Collection, Volume 2: *How Do We Explore?*, visit: <http://oceanexplorer.noaa.gov/okeanos/edu/collection/hdwe.html>

To request an *Engineering to Explore the Ocean* workshop in your region, please contact: usnastem@usna.edu

Day 1 Agenda		Day 2 Agenda	
8:15	Welcome/ Introductions Introduction to U.S. Naval Academy / USNA STEM Introduction to NOAA OER / <i>Okeanos Explorer</i> Agenda OER Exploration Strategy & Modes of Operation Book Overview / NGSS USNA Engineering Design	4:30	Hydraulics and Biolooids ACTIVITY: Invent a Robot Hydraulic Arm
8:45	SONAR/Multi-beam Mapping Intro ACTIVITY: Wet Maps	5:30	Telepresence A Day in the Life of an Ocean Explorer
9:15	ACTIVITY: Using Vernier Tools	5:45	SEAPERCH BUILD: Control Boxes
10:00	Intro to Water Column Investigations ACTIVITY: Oceanographic Yo-yo	7:00	SEAPERCH BUILD: Ballasting and Operation in Pool
10:30	Break	7:45	Wrap up/Evaluation
10:45	ACTIVITY: Build a Sensor		
11:15	Intro to ROVs Video: Deep Discoverer ROV ACTIVITY: I, Robot, Can Do That		
12:00	Lunch		
12:30	SEAPERCH BUILD: Sea Perch Frames, Motors		
3:30	What Little Herc (ROV) Saw		

Figure 4. Schedule for the 1.5 day Engineering to Explore the Ocean workshop. The full-day takes place during regular school hours, and the half-day is offered in the evening (after school hours) in order to minimize teacher time away from class.

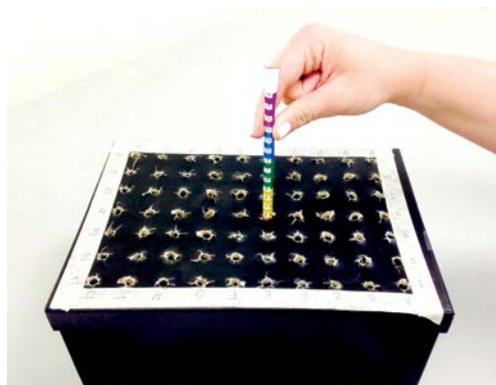
Image courtesy of USNA STEM Center.

Figure 5 (left). Teachers collect depth “soundings” and make a bathymetric map of concealed features in the NOAA OER Wet Maps lesson.

Image courtesy of USNA STEM Center.

Figure 6 (right). Teachers gather temperature and pH data from different water samples to identify the location of a simulated hydrothermal vent in the NOAA OER Oceanographic Yo-Yo lesson.

Image courtesy of USNA STEM Center.



For more information regarding specific NGSS performance expectations and NOAA OER, please go to: http://oceanexplorer.noaa.gov/oceanexplorer/edu/collection/hdwe_ngss.pdf

is then attempted: participants collect SONAR data using a Vernier motion detector that relies on sound waves to detect objects (in this case, boxes) on a concealed, artificial seafloor. In another lesson, *The Oceanographic Yo-Yo* (Figure 6), CTD water samples are simulated using cups of chilled or heated water with trace amounts of vinegar. Participants collect temperature and pH data from each sample in order to determine which water sample would mostly likely have occurred closest to a hydrothermal vent on the seafloor. Finally, during the *What Little Herc Saw* lesson, authentic video footage from one of the *Okeanos Explorer*'s ROVs is viewed and benthic organisms are identified and recorded to simulate the method of investigation that takes place aboard the vessel and to introduce the concept of biodiversity. Each of the lessons has been specifically mapped with regard to NGSS performance expectations, science and engineering practices, disciplinary core ideas, and crosscutting concepts (NOAA, 2015b). For example, *What Little Herc Saw* supports NGSS performance expectation MS-LS2-1: “Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem” (NGSS Lead States, 2013).

Ocean exploration technology, such as multibeam SONAR and telepresence communication via satellite, feature strongly in the workshop, background, and activities. During these professional development opportunities, facilitators strive to deconstruct seemingly mysterious technology so participants can more easily understand how the science and engineering are integrated. For example, using hands-on methodology, workshop participants are guided to construct a pressure sensor using cardstock, foil, tape, a watch battery, and a light emitting diode (LED) (Figure 7). In the process, participants learn how to engineer a simple sensor that completes an electrical circuit in response to a physical change. This provides a foundation for conceptualizing more complex sensors found on underwater ROVs.

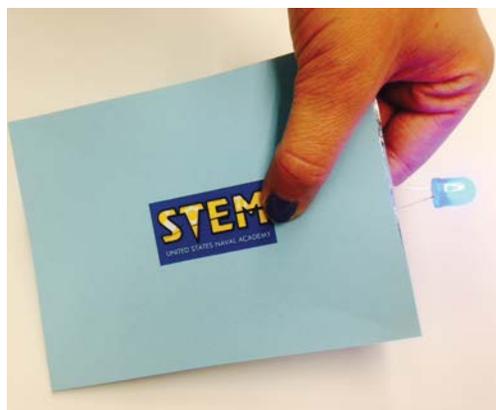
With the implementation of NGSS comes particular emphasis on integrating engineering design into K-12 science curriculum. “From a teaching and learning point of view, it [engineering design]

Figure 7. Using household materials, teachers engineer a pressure sensor that lights up when pressure is applied, providing a deeper understanding of how ROV sensors function.

Image courtesy of USNA STEM Center.

Figure 8. Teachers construct a hydraulic actuator during the Invent a Robot lesson.

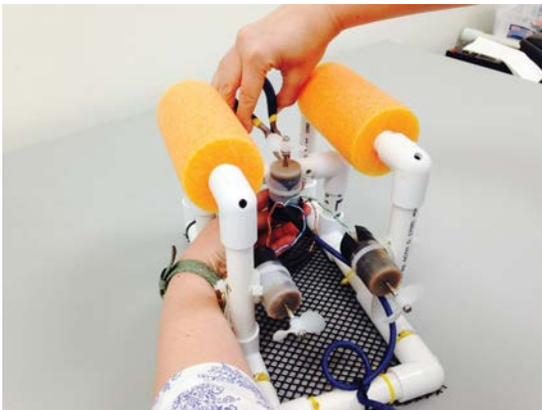
Image courtesy of Dauphin Island Sea Lab.



is the iterative cycle of design that offers the greatest potential for applying science knowledge in the classroom and engaging in engineering practices” (National Research Council, 2012, pp. 201-202). To introduce the engineering design process, workshop participants use oral syringes, plastic tubing, machine screws, and cardboard to create a hydraulic actuator during the *Invent a Robot* lesson (Figure 8). Once this is mastered, participants are then introduced to the different components of an ROV, specifically the different systems of a SeaPerch ROV that they will be building: the PVC frame (structural system), the motors for propulsion (mechanical system), and the control box (electrical system) (Figure 9). During the workshop’s SeaPerch build, participants learn to use essential engineering tools such as PVC pipe cutters, a drill, and a soldering iron. After the SeaPerch ROV is built, the robot is then tested and ballasted in a swimming pool (Figure 10). Over time, workshop participants experience a conceptual progression from the *Invent a Robot* activity, to the discussion on ROV design, to the

The engineering design process involves defining the problem, gathering relevant information, brainstorming possible solutions, analyzing potential solutions, selecting the most promising, and testing the solution.

USNA’s STEM Center provides applied STEM methodology and best practices to K-16 educators. Workshops include topics in project-based learning and experiential learning. To learn more about USNA’s educator training, please visit: <http://www.usna.edu/STEM/teachers.php>



SeaPerch build. They can then conceptualize the engineering behind more robust ROVs with sensors and cameras found on the *Okeanos Explorer*. This portion of the workshop supports the NGSS Disciplinary Core Ideas: Defining and Delimiting Engineering Problems, Developing Possible Solutions, and Optimizing the Design Solution (NGSS Lead States, 2013).

Assessment and Impact

Since 2014, several sessions of the *Engineering to Explore the Ocean* workshop have been held in Anne Arundel County, MD, Prince Georges County, MD, and Dayton, OH. Workshop participants were surveyed following each event, and survey responses have been very positive. Participants report that this opportunity advanced their professional development goals, taught them content, and provided numerous resources and activities for use in their classroom. One participant remarked that she learned “a way to engage students in ocean exploration in a hands-on manner, and how easy it was to actually build a remote controlled vehicle that can be used for real science” (participant response, Workshop Survey, 2014).

Anonymous surveys were administered to Prince Georges County participants at the end of the workshop on December 2, 2014. Survey

Figure 9 (left). Participants mount the SeaPerch ROV motors after discussing waterproof systems and propulsion.

Image courtesy of USNA STEM Center.

Figure 10 (right). When the SeaPerch ROV build is complete, teachers learn to ballast their SeaPerch and test its operation underwater.

Image courtesy of USNA STEM Center.

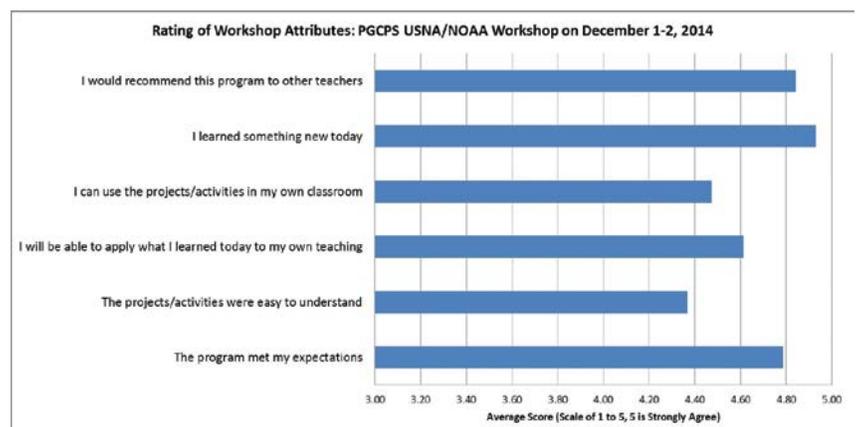


Figure 11. Prince George’s County teacher responses to follow-up survey on December 2, 2014 (n = 58).

Resources

NOAA Office of Ocean Exploration and Research

For more information about NOAA's OER Education Program, please visit: <http://oceanexplorer.noaa.gov/>

For educational materials from the NOAA Ship *Okeanos Explorer*, please visit: <http://oceanexplorer.noaa.gov/okeanos/edu/>

Multibeam SONAR: <http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-MMBkgnd.pdf>

Water Column Exploration: <http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-WCIntro.pdf>

ROVs: <http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-URintro.pdf>

Telepresence: <http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-TPbkgnd.pdf>

Expeditions: <http://oceanexplorer.noaa.gov/explorations/explorations.html>

Live expedition video: <http://oceanexplorer.noaa.gov/okeanos/media/exstream/exstream.html>

SeaPerch

For more information about SeaPerch ROVs and the underwater robotics program, please visit: <http://www.seaperch.org/>

USNA STEM Center for Education and Outreach

For more details regarding USNA's STEM education and outreach program, please go to: <http://www.usna.edu/STEM/>

To learn more about USNA's educator training, please visit: <http://www.usna.edu/STEM/teachers.php>

To request a workshop in your region, please contact: usnastem@usna.edu

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questions employed open-ended response or 5-point Likert questions where 1 is *Strongly Disagree* and 5 is *Strongly Agree*. Approximately 58 teacher surveys were collected and analyzed. On average, participants reported agreement that they learned something new and could apply what they learned pedagogically (Figure 11).

Conclusion

Offered as a collaboration between NOAA OER and USNA STEM, the *Engineering to Explore the Ocean* professional development workshop offers participants the opportunity to advance ocean literacy, to engage in ocean exploration as a result of technological innovation, to experience engineering design through the building of an ROV, and to explore the hands-on methodology of project-based learning. The breadth and depth of workshop content and activities strongly support the NGSS which advocate carrying out scientific investigations, analyzing and interpreting data, and employing engineering design to apply scientific knowledge. Workshop participants gain essential skills for building a SeaPerch ROV, incorporating ocean exploration curriculum in their classrooms, and establishing a SeaPerch club at their school. They also cultivate essential STEM content knowledge and pedagogy for use in their classroom. Through ongoing workshops, NOAA OER and USNA STEM are committed to advancing ocean-literacy and hands-on, experiential learning among our nation's educators and ultimately, their students.

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Susan Haynes is the Education Program Manager for NOAA's Office of Ocean Exploration and Research (OER), contracted by Collabralink Technologies, Inc. She manages both onsite and online Ocean Exploration teacher professional development in cooperation with 15 national Alliance partners and the College of Exploration. OER currently focuses a significant portion of their education programming on the expeditions associated with the NOAA Ship *Okeanos Explorer*, America's first Federal ship of exploration. Prior to arriving at NOAA in May 2008, Susan spent four years as the Director for the National Ocean Sciences Bowl at the Consortium for Ocean Leadership (CORE division) in Washington, D.C. Formerly an Education Specialist for Virginia Sea Grant at the Virginia Institute of Marine Science, her past work has included working with scientific faculty to design graduate courses for teachers and developing classroom activities using authentic research data. She has also been an Education Specialist at Oregon Coast Aquarium and National Aquarium in Baltimore and was the 2013-2014 president of the National Marine Educators Association. Susan can be reached at susan.haynes@noaa.gov.

Melissa Ryan is a contractor who serves as Assistant Project Manager for NOAA Office of Ocean Exploration and Research's (NOAA OER) Deep Submergence Engineering Group. This highly skilled group of engineers designs, operates and maintains NOAA's underwater robotic systems used for ocean exploration. She also leads and manages all aspects of a multi-year, multi-national search for a famous Revolutionary War shipwreck. Previously Melissa worked for seven years as a Professional Development Specialist at NOAA OER, where she coordinated and instructed a national ocean exploration education program for teachers around the country. Melissa also developed and instructed the U.S. Naval Academy's first online course on the scientific, historic and engineering aspects of historic shipwrecks.