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PHAEDRA 2006:

Partnership for Hellenic-American Exploration in the Deep Regions of the Aegean

My Wet Robot

Focus
Underwater robotic vehicles

Grade Level
9-12 (Physical Science))

Focus Question
What are some workable solutions to typical problems involved with the design of practical underwater robots?

Learning Objectives
Students will be able to discuss the advantages and disadvantages of using underwater robots in scientific explorations.

Given a specific exploration task, students will be able to identify key design requirements for a robotic vehicle that is capable of carrying out a task.

Students will be able to describe practical approaches to meet identified design requirements.

(Optional) Students will be able to construct a robotic vehicle capable of carrying out an assigned task.

Materials
❒ None

Audio/Visual Materials
❒ None

Teaching Time
Two or three 45-minute class periods, plus time for students to complete their projects

Seating Arrangement
Groups of 2-4 students

Maximum Number of Students
32

Key Words
AUV
ROV
Robotic vehicle
Underwater archaeology

Background Information
"Man hoisted sail before he saddled a horse. He poled and paddled along rivers and navigated the open seas before he traveled on wheel along a road. Watercraft were the first of all vehicles." Thor Heyerdahl, *Early Man and the Ocean* (Doubleday, 1979)

Mariners have travelled the Aegean Sea since Neolithic times (the Stone Age: 6,500 – 3,200 BC). Motives for their voyages ranged from trading to exploration to warfare, making seafaring prominent in the history of cultures that include the Minoans (ca 2,600 – 1,450 BC), Mycenaeans (ca 1,600 – 1,100 BC), Ancient Greeks (776 – 323 BC), and Hellenistic Greeks (323 – 146 BC). Remnants of ancient ocean voyages (i.e., shipwrecks) can provide information about trading patterns, sociopolitical networks, technological development and many other unique insights into these cultures, but a variety of factors makes it difficult to find such remnants. One problem is that interactions between cultures were not always peaceful, and destroying important shipping assets would have been an obvious step toward conquering an opponent.

Another obstacle is the same feature that makes ancient shipwrecks so valuable: their age. In addition to increasing the severity of deterioration by biological and chemical processes, the passage of time also increases the likelihood that ancient shipwrecks will be impacted by natural disasters. The southern Aegean region has experienced numerous severe volcanic events and tsunamis, including the eruption of a volcano near a small island called Thera (also known as Santorini), sometime between 1,650 and 1,450 BC. This eruption is estimated to have been four times more powerful than the Krakatoa volcano of 1883, left a crater 18 miles in diameter, spewed volcanic ash throughout the Eastern Mediterranean, and may have resulted in global climatic impacts. Coupled with earthquakes and a tsunami, the volcano destroyed human settlements, fleets of ships, and may have contributed to the collapse of the Minoan civilization. More recently, the 1650 AD eruption of the Columbo volcano—7 km to the northeast of Thera—produced ash, pumice, toxic gases, and a tsunami that devastated the coasts of surrounding islands.

Even if ancient shipwrecks survive natural disasters (and those caused by humans), finding, exploring and scientifically studying these sites are complicated by the fact that much of the Aegean Sea is relatively deep. Total darkness and an environment that is extremely hostile to humans have, until recently, been obstacles that are virtually insurmountable. Technological advances over the past decade, though, have made deep water archaeology a much more feasible endeavor. The PHAEDRA 2006 Expedition will use the SeaBED Autonomous Underwater Vehicle to search for deepwater shipwrecks, as well as conduct precise geological and chemical surveys in the vicinity of underwater volcanoes in the Aegean Sea. "Autonomous Underwater Vehicle" (AUV) means that this is a self-contained underwater robot that operates without a physical cable or tether such as those used on remotely operated vehicles (ROVs). SeaBED is designed specifically to provide precise maps and high-resolution three-dimensional color images of seafloor features, as well as to carry equipment for measuring physical and chemical properties of the surrounding seawater. Using SeaBED to map and document survey sites frees archaeologists from tedious measuring and sketching tasks and allows them to concentrate on interpreting survey results. For more information about SeaBED, visit http://www.whoi.edu/institutes/doei/general/news_seabed.pdf.

This expedition is an unusual collaboration between four U.S. research institutions and the Greek Ephorate of Underwater Antiquities (Hellenic Ministry of Culture) and Hellenic Centre for Marine Research. Scientists from Woods Hole Oceanographic Institution, Massachusetts Institute of Technology, Franklin W. Olin College of Engineering, and Johns Hopkins University will work with their Greek counterparts to use underwater robots to make detailed archaeological surveys of two ancient shipwrecks in deep water. One of these is believed to be the wreck of a Classical or Hellenistic ship that lies in a depth of about 500 m off the island of Hythnos in the central Aegean Sea. The other is believed to be the remains of a Byzantine period vessel that sank in 110 m of water off Porto Kuofo in the northern Aegean.

A third survey area will focus on a portion of the Aegean seafloor that scientists believe was unaffected by the Theran eruption and may consequently contain very ancient shipwrecks that have not yet been discovered. This area is close to the Columbo volcano, but has never been explored. To learn more about volcanic processes in this area, surveys will precisely map the seafloor and gather chemical data that will provide clues about volcanic activity as well as unusual geologic features such as cold seeps and volcanic vents.

In this activity, students will design and, optionally, build an underwater robotic vehicle capable of performing specified tasks.

Learning Procedure

1. To prepare for this lesson:
   a. Review the background essays for the PHAEDRA 2006 Expedition at http://oceanexplorer.noaa.gov/explorations/06greece/, as well as the Ocean Explorer Web pages on underwater robotic vehicles, indexed at http://oceanexplorer.noaa.gov/technology/subs/subs.html.

   b. Decide on the desired level of complexity for this lesson. The simplest, quickest, and least expensive approach is to simply have students design robotic vehicles that could be capable of performing prescribed tasks. A more involved approach would be to require the robotic vehicles to be capable of autonomous activity, so that students would have to incorporate programmable robotics such as Lego "Mindstorms" components. The most involved (and also the most fun and rewarding) approach is to require students to actually construct the robots they design. If you plan to have students construct their robotic vehicles, you may also want to review the books by Harry Bohm listed under Resources. If you opt for one of the more complex approaches, at least a month should be available for students to complete their assignment; more time would be better.

   c. If students do not have access to the internet, make copies of relevant materials on underwater robotic vehicles from the Web site referenced above.

2. Introduce the PHAEDRA 2006 Expedition, emphasizing the role of the SeaBED AUV. You may want to show video clips from some of the sites referenced in Step 1 to supplement this discussion. Briefly discuss the advantages and disadvantages of underwater robots compared to submersibles. Advantages include smaller size and construction cost, since they do not have to accommodate humans, and reduced risks to human life. The major drawback is that the human presence is lost, and this can make visual surveys and evaluations more difficult. Tethered robots also are constrained to some extent by their cabled connection to the support ship.

3. Tell students that their assignment is to design an underwater robotic vehicle that they could construct and that would be capable of moving in a horizontal direction at a fixed depth. You may also want to include a requirement that the robot must collect some type of information about the surrounding environment (temperature, visual image, etc.). If you want to require that the vehicles be capable of autonomous activity and/or actually constructed, add those instructions as well.

   To help students get started, lead a brainstorming session of key components or systems that would have to be included in this kind of vehicle, such as:
   - power system,
   - propulsion system,
   - communication system,
   - buoyancy control system, and
   - information gathering system(s).

   Discuss specific requirements for each of these systems. Emphasize that the intention of this assignment is for students to design an underwater robotic vehicle that they could construct (whether you actually require them to do so or not), so students' solutions to these requirements should be practical and involve materials to which they have access. Assign "milestone" dates by which certain tasks should have been completed. Have each group present a periodic progress report, identifying problems that have been encountered and proposed solutions.

There are numerous reports, case studies, and other information on the internet about underwater robotics projects, and students should be encouraged to locate these and learn from prior experience. Procedures for waterproofing motors and other components, programs for autonomous control of simple movements, and many other "lessons learned" are available. Tell students to be sure to document the sources for any "prior knowledge" that they use in designing their robots, and to keep a notebook in which they record the assigned requirements for their robot, their approaches to providing key systems, and (if their assignment includes constructing a robot) test procedures and results for each of these systems as well as for the assembled robotic vehicle.

On the date assigned for project completion, each group should present a report of their design solutions and demonstrate their assembled robotic vehicle (if this was part of their assignment).

The Bridge Connection

www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click "Ocean Science Topics," then "Human Activities," then "Technology" for links to resources about submersibles, ROVs, and other technologies used in underwater exploration.

The "Me" Connection

Have students write a brief essay describing how robots are (or may be) of personal benefit.

Connections to Other Subjects

English/Language Arts, Mathematics

Assessment

Notebooks, project reports, and completed robots (if assigned) provide opportunities for assessment.

Extensions

Have students visit http://oceanexplorer.noaa.gov/explorations/06greece/ to keep up with the latest discoveries from the PHAEDRA 2006 Expedition

Resources

NOAA Learning Objects

http://www.learningdemo.com/noaa/ – Click on the links to Lessons 1, 2, 4 and 5 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Mid-Ocean Ridges, Subduction Zones and Chemosynthesis and Hydrothermal Vent Life.

Other Relevant Lessons from the Ocean Exploration Program

Lost City Chemistry Detectives

http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05_chemdetect.pdf
6 pages, 411k) (from the Lost City 2005 Expedition)

Focus (Chemistry/Earth Science) - Chemistry of the Lost City Hydrothermal Field

In this activity, students will be able to compare and contrast the formation processes that produce black smokers and the Lost City hydrothermal field, describe the process of serpentinization and how this process contributes to formation of chimneys at the Lost City hydrothermal field, and describe and explain the chemical reactions that produce hydrogen and methane in Lost City hydrothermal vent fluids.

The Big Balancing Act

http://oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_balancing.pdf
(9 pages, 1.3Mb) (from the New Zealand American Submarine Ring of Fire 2005 Expedition)

Focus: Hydrothermal vent chemistry at subduction volcanoes (Chemistry/Earth Science)

In this lesson, students will be able to define and describe hydrothermal circulation systems, explain the overall sequence of chemical reactions that occur in hydrothermal circulation systems, compare and contrast "black smokers" and "white smokers," and use data on chemical enrichment in hydrothermal circulation systems to make inferences about the relative significance of these systems to ocean chemical balance compared to terrestrial runoff.

Where There's Smoke, There's ...

http://oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_smoke.pdf
(6 pages, 680k) (from the New Zealand American Submarine Ring of Fire 2005 Expedition)

Focus: Hydrothermal vent chemistry at subduction volcanoes (Chemistry)

In this lesson, students will be able to use fundamental relationships between melting points, boiling points, solubility, temperature, and pressure to develop plausible explanations for observed chemical phenomena in the vicinity of subduction volcanoes.

Do You Have a Sinking Feeling?

http://oceanexplorer.noaa.gov/explorations/06blacksea/background/edu/media/06blacksea_sinking.pdf
(from the Aegean and Black Sea 2006 Expedition)

Focus: Marine archaeology (Earth Science/Mathematics)

In this activity, students plot the position of a vessel given two bearings on appropriate landmarks, draw inferences about a shipwreck given information on the location and characteristics of artifacts from the wreck, and explain how the debris field associated with a shipwreck gives clues about the circumstances of the sinking ship.

What's the Difference?

http://oceanexplorer.noaa.gov/explorations/06blacksea/background/edu/media/06blacksea_difference.pdf
(from the Aegean and Black Sea 2006 Expedition)

Focus: Volcanic processes at convergent and divergent tectonic plate boundaries (Earth Science)

Students will be able to compare and contrast volcanoes at convergent and divergent plate boundaries; identify three geologic features that are associated with most volcanoes on Earth; and explain why some volcanoes erupt explosively while others do not.

I, Robot, Can Do That!

http://oceanexplorer.noaa.gov/explorations/06blacksea/background/edu/media/06blacksea_robot.pdf
(from the Aegean and Black Sea 2006 Expedition)

Focus: Underwater Robotic Vehicles for Scientific Exploration

In this activity, students will be able to describe and contrast at least three types of underwater robots used for scientific explorations, discuss the advantages and disadvantages of using underwater robots in scientific explorations, and identify robotic vehicles best suited to carry out certain tasks.

Designing Tools for Ocean Exploration

http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr9_12_l1.pdf
(13 pages, 496k) (from the 2002 Galapagos Rift Expedition)

Focus: Ocean Exploration

In this activity, students will understand the complexity of ocean exploration; learn about the technological applications and capabilities required for ocean exploration; discover the importance of teamwork in scientific research projects; and develop the abilities necessary for scientific inquiry.

The Puzzle of the Ice Age Americans

http://oceanexplorer.noaa.gov/explorations/02fire/background/education/media/ring_puzzle_9_12.pdf
(8 pages, 100k) (from the 2002 Submarine Ring of Fire Expedition)

Focus: Anthropology, Earth Science - Origin of the first humans in the Americas

In this activity, students will be able to describe alternative theories for how the first humans came to the Americas and explain the evidence that supports or contradicts these theories, explain how exploration of a submerged portion of the North American west coast may provide additional insights about the origin of the first Americans, and describe the role of skepticism in scientific inquiry.

Other Resources and Links

http://oceanexplorer.noaa.gov/explorations/06greece/ – Web site for the PHAEDRA 2006 Expedition

Bohm, H. and V. Jensen. 1998. Build Your Own Programmable Lego Submersible: Project: Sea Angel AUV (Autonomous Underwater Vehicle). Westcoast Words. 39 pages.

Bohm, H. 1997. Build your own underwater robot and other wet projects. Westcoast Words. 148 pages.

http://ina.tamu.edu/vm.htm – The Institute of Nautical Archaeology's Virtual Museum

http://projectsx.dartmouth.edu/history/bronze_age/ – Dartmouth University Web site, "Prehistoric Archaeology of the Aegean," with texts, links to other online resources, and numerous bibliographic references

http://newton.physics.wwu.edu:8082/jstewart/scied/earth.html – Earth science education resources

http://www.sciencegems.com/earth2.html – Science education resources

http://www-sci.lib.uci.edu/HSG/Ref.html – References on just about everything

National Science Education Standards

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard D: Earth and Space Science
- Structure of the Earth system

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in society

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.
- *Fundamental Concept b.* An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

Essential Principle 6.
The ocean and humans are inextricably interconnected.
- *Fundamental Concept b.* From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.
- *Fundamental Concept c.* The ocean is a

source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.

- *Fundamental Concept d.* Much of the world's population lives in coastal areas.
- *Fundamental Concept f.* Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).

Essential Principle 7.
The ocean is largely unexplored.

- *Fundamental Concept a.* The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
- *Fundamental Concept b.* Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
- *Fundamental Concept d.* New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
- *Fundamental Concept f.* Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

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