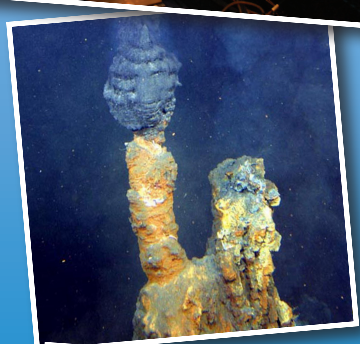
DEEP SEA EXPLORATION
INDEX2010
Sangihe Talaud
Indonesia-USA

INDEX/SATAL 2010

Exploring the Unknown



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lesson plan

Focus

Strategies for deep ocean exploration

Grade Level

9-12 (Earth Science)

Focus Question

What methods do scientists use to explore places that have never been seen before?

Learning Objectives

- Students will be able to discuss factors that influenced exploration strategies of the Lewis and Clark and *Challenger* Expeditions.
- Students will be able to describe the overall exploration strategy developed for the NOAA Ship *Okeanos Explorer.*
- Students will be able to discuss the concept of anomalies as it applies to deep ocean exploration, and how scales of measurement influence detection of anomalies.

Materials

- ❑ Copies of the *Exploration Strategies Inquiry Guide,* one for each student group

Audio-Visual Materials

- ❑ None

Teaching Time

One or two 45-minute class periods, plus time for student research

Seating Arrangement

Groups of 4-6 students

Maximum Number of Students

30

Key Words

Exploration Strategy
Lewis and Clark Expedition
HMS *Challenger* Expedition
The NOAA Ship *Okeanos Explorer*

The NOAA Ship *Okeanos Explorer*
Formerly: USNS *Capable*
Launched: October 28, 1988
Transferred to NOAA: September 10, 2004
Commissioned: August 13, 2008
Class: T-AGOS
Length: 224 feet
Breadth: 43 feet
Draft: 15 feet
Displacement: 2,298.3 metric tons
Berthing: 46 (19 Mission/science)
Speed: 10 knots
Range: 9600 nm
Endurance: 40 days

Systems and Instumentation:
Kongsberg EM302 Multibeam rated to 7,000 m
SBE 911 Plus CTD
ROVs -
Little Hercules - 4,000 m depth rating; USBL tracking; depth, altitude, attitude/heading sensors; Seabird SBE 49 FastCat CTD; HD camera and HMI lights
Camera platform with depth/altitude/heading sensors, HD cameraand HMI lights.
Telepresence

Operations:
Ship crewed by NOAA Commissioned Officer Corps and civilians through NOAA's Office of Marine and Aviation; Mission equipment operated by NOAA's Office of Ocean Exploration and Research

For more information, visit http://oceanexplorer.noaa.gov/okeanos/welcome.html.

Images from Page 1 top to bottom:
The ROV Hercules being lowered into the water from the NOAA Ship *Okeanos Explorer*. Image credit: NOAA OER.

NOAA scientists examining live video feed from the ROV Hercules. Image credit: NOAA OER.

Mussels, shrimp, limpets, and crabs cover the slope of an underwater volcano near a hydrothermal vent. Image credit NOAA
http://www.photolib.noaa.gov/bigs/expl0071.jpg

Black smokers on the Kermadec Arc. Image courtesy of New Zealand American Submarine Ring of Fire 2007 Exploration, NOAA Vents Program, the Institute of Geological & Nuclear Sciences and NOAA-OE.
http://oceanexplorer.noaa.gov/explorations/07fire/logs/july31/media/brothers_blacksmoker_600.jpg

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

During the summer of 2010, scientists from Indonesia and the United States will work together on an expedition to explore the deep ocean surrounding Indonesia. This mission is called INDEX/SATAL 2010, since the expedition is focussed on INDonesia, EXploration, and the Sangihe Talaud (SATAL) region. Working from the Indonesian Research Vessel *Baruna Jaya IV* and the NOAA Ship *Okeanos Explorer*, these ocean explorers expect to find new deep-sea ecosystems, undiscovered geological features, and living organisms that have never been seen before. New discoveries are always exciting to scientists; but information from ocean exploration is important to everyone, because:

- Biodiversity in deep-sea ecosystems includes new species that can provide important drugs and other useful products;
- Some deep-sea ecosystems include organisms that can be used for human food;
- Information from deep ocean exploration can help predict earthquakes and tsunamis; and
- Human benefits from deep ocean systems are being affected by changes in Earth's climate and atmosphere.

In addition to being the first joint Indonesia-USA ocean exploration expedition, the INDEX/SATAL 2010 mission also marks the maiden voyage of the NOAA Ship *Okeanos Explorer*. As "America's Ship for Ocean Exploration," the *Okeanos Explorer* is the only U.S. ship whose sole assignment is to systematically explore Earth's largely unknown ocean for the purposes of discovery and the advancement of knowledge.

Exploring the unknown is a challenging undertaking. Long voyages into remote areas and scientific studies both require careful planning to minimize risks, maximize the chances of obtaining useful information, and make the best use of financial resources. Explorers must do this kind of planning without knowing exactly what they will encounter or what they will need to do to achieve their objectives. The exploration strategy designed for the *Okeanos Explorer* has taken years to develop, and has involved dozens of ocean explorers, engineers, ocean scientists, and visionaries.

This lesson guides student inquiries into strategies for exploration, and introduces key capabilities and procedures that will enable the *Okeanos Explorer* to fulfill her mission of finding new and unusual features in unexplored parts of Earth's ocean. The ship is also charged with gathering key information that will support more detailed investigations by subsequent expeditions.

Learning Procedure

1. To prepare for this lesson:
   (a) Review introductory essays for the INDEX SATAL 2010 Expedition at http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html
   (b) Review information about the importance of deep ocean exploration in the Background section of the "Earth's Ocean is 95% Unexplored: So What?" lesson;
   (c) Make copies of the *Exploration Strategies Inquiry Guide*.

2. Briefly introduce the INDEX/SATAL 2010 Expedition, and point out that this expedition is the maiden voyage of the *Okeanos Explorer*, which is the only U.S. ship whose sole assignment is to systematically explore Earth's largely unknown ocean for the purposes of discovery and the advancement of knowledge. Ask students for their ideas about why this kind of exploration might be important, and highlight some of the reasons referenced in Step 1b. Be sure students understand that discoveries of deep sea chemosynthetic communities during the last 30 years are major scientific events that have changed many assumptions about life in the ocean and have opened up many new fields of scientific investigation.

3. Tell students that their assignment is to investigate strategies used by other expeditions to explore unknown territories, and to invent a strategy that might guide the *Okeanos Explorer* on its voyages of discovery. Provide each student or student group with a copy of the *Exploration Strategies Inquiry Guide*. You may want to have individual students or groups focus on only the Lewis and Clark Expedition or the *Challenger* Expedition, or have them answer questions about both expeditions.

4. Lead a discussion of students' responses to questions about previous expeditions to explore the unknown. The following points should be included:

Lewis and Clark Expedition

- Thomas Jefferson's primary motivation for exploring the American West was developing commerce, specifically finding the most direct and practicable routes for water transport across the continent. Related to this mission was the requirement that the explorers should contact and develop friendly relations with native American tribes. Jefferson was also a keen citizen scientist, and his instructions for the Expedition also stated that observations should be made of soils, plants, animals, minerals, geologic formations, and climatic conditions.

- The overall plan for the Expedition's route was to follow the Missouri River upstream as far as possible, and then find a route to the Pacific Ocean. Since much of the Missouri River was unexplored, Lewis and Clark had no idea how close the headwaters of the Missouri would be to the Pacific, nor whether any route between them actually existed.

- The Expedition made extensive observations and collections in keeping with the broad instructions described above, with particular emphasis on detailed maps.

- Technical instruments included mariner's compass and surveying instruments, portable microscope, and hydrometers. Information about natural history was collected primarily by visual observation and recorded as drawings, notes, and specimens.

The official report of the Expedition required eight years to complete after the explorers returned, and includes two volumes totalling 992 pages.

HMS *Challenger* Expedition

- The HMS *Challenger* Expedition was organized and funded to examine the deep-sea floor and address specific scientific objectives:
  - To investigate depth, temperature, circulation, specific gravity and penetration of light in the deep sea;
  - To determine the chemical composition of seawater at various depths from the surface to the bottom, the organic matter in solution and the particles in suspension;
  - To ascertain the physical and chemical character of deep-sea deposits and the sources of these deposits; and
  - To investigate the distribution of organic life at different depths and on the deep seafloor.

  In addition, the Expedition was instructed to obtain photographs of "native races," and the information that was recorded about the indigenous people proved to be extremely valuable, because many island cultures changed rapidly in subsequent years.

  You may also want to point out that commercial interest in the deep ocean was being stimulated by the desire to lay submarine telegraph cables, and that there was scientific controversy over whether there was any life at all in the ocean below 1800 feet.

- The Expedition's route included the North and South Atlantic, Indian, and Pacific Oceans (http://oceanexplorer.noaa.gov/explorations/03mountains/background/challenger/media/route.html). Along this route, 362 official stations were established at which data were collected.

- A standard set of data was collected at each of 360 stations along their route. Samples and data were carefully returned to Scotland for systematic analysis and documentation. The standard set of observations made and samples taken at each of the 360 stations were:
  - water depth
  - temperature at various depths
  - weather conditions
  - water conditions at surface and sometimes at depth
  - seafloor samples
  - water samples for later chemical analysis
  - samples of plant and animal life collected with dredges, trawls, and sometimes plankton nets from various depths.

- Primary technical instruments were weighted ropes for measuring depth; dredges and nets; thermometers; hydrometers; and water sampling bottles.

The final reports from the HMS *Challenger* Expedition occupy 50 volumes with a total of 29,552 pages, and required 19 years to complete after the Expedition ended.

5. Lead a discussion about exploration strategies that might guide *Okeanos Explorer* missions. Have students present their ideas, then relate these to the following summary:

   The overall *Okeanos Explorer* strategy is based on finding anomalies; conditions or features that are different from the surrounding environment. This is because anomalies may point the way to new discoveries, which are part of the ship's mission. Changes in chemical properties of seawater, for example, can indicate the presence of underwater volcanic activity, hydrothermal vents, and chemosynthetic communities. Once an anomaly is detected, the exploration strategy shifts to obtaining more detailed information about the anomaly and the surrounding area. An important concept underlying this strategy is a distinction between exploration and research. As a ship of discovery, the role of the *Okeanos Explorer* is to locate new features in the deep ocean, and conduct preliminary investigations that provide enough data to characterize the site and enable other scientists to determine whether or not to follow up with future expeditions.

   This strategy involves three major activities:
   - Underway reconnaissance;
   - Water column exploration; and
   - Site characterization.

Underway reconnaissance involves mapping the ocean floor and water column while the ship is underway, and using other sensors to measure chemical and physical properties of seawater. Water column exploration involves making measurements of chemical and physical properties "from top to bottom" while the ship is stopped. In some cases these measurements may be made routinely at pre-selected locations, while in other cases they may be made to decide whether an area with suspected anomalies should be more thoroughly investigated. Site characterization involves more detailed exploration of a specific region, including obtaining high quality imagery, making measurements of chemical and physical seawater properties, and obtaining appropriate samples.

Key technologies involved with this strategy include:

- Multibeam sonar mapping system;
- CTD and other electronic sensors to measure chemical and physical seawater properties; and
- A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery in depths as great as 4,000 meters.

A fourth technological capability that is essential to the *Okeanos Explorer* exploration strategy is advanced broadband satellite communication. This capability provides the foundation for "telepresence;" technologies that enable people to observe and interact with events at a remote location. Telepresence allows live images to be transmitted from the seafloor to scientists ashore, classrooms, newsrooms and living rooms, and opens new educational opportunities that are a major part of the *Okeanos Explorer*'s mission for advancement of knowledge. In addition, telepresence makes it possible for shipboard equipment to be controlled by scientists in shore-based Exploration Command Centers. In this way, scientific expertise can be brought to the exploration team as soon as discoveries are made, and at a fraction of the cost of traditional oceanographic expeditions.

Students may suggest ocean currents as an important feature that should be measured. *Okeanos Explorer* presently does not have this capability, but upgrade plans include adding an instrument called an acoustic doppler current profiler (ADCP). An ADCP is a type of sonar that is capable of measuring current velocity and direction at a series of depths.

These technologies are discussed in more detail in the "Tools of Discovery" lessons. Be sure students realize that the recognition of anomalies may be affected by a variety of factors, including the scale at which observations are made, who is making the observations, and how the observations are made. For example, if observations of chemical and physical seawater properties are made at 100 ft intervals, anomalies are more likely to be missed than if these observations are made at intervals of 1 m (which is possible with CTD equipment aboard the *Okeanos Explorer*). Or, a bottom feature imaged by multibeam sonar that might be interpreted differently by a biologist and a geologist. This is also a good example of the importance of telepresence in the *Okeanos Explorer* exploration strategy. Finding anomalies in the deep ocean is highly dependent upon the technology that is available to make observations. Okeanos Explorer carries observation tools that obviously were not available aboard HMS *Challenger* (but *Challenger* scientists still made many important discoveries!); but even with state-of-the-art technology, it is also likely that some anomalies will be missed because they can only be observed with instruments that are not yet available to ocean explorers.

Encourage students to make other comparisons between *Okeanos Explorer* missions and the Lewis and Clark and HMS *Challenger* Expeditions. For example:

- Both the Lewis and Clark and HMS *Challenger* Expeditions were largely focused on documenting features and conditions in the areas they visited. The *Okeanos Explorer* strategy includes this kind of documentation as well, but in also includes an active search for unusual conditions (anomalies) that may point the way to previously-unknown features or processes.

- The HMS *Challenger* Expedition began in December 1872 and ended in May 1876; more than half of this time was spent in various ports around the world; the Lewis and Clark Expedition began on May 14, 1804 and ended on September 23, 1806; the *Okeanos Explorer* has an at-sea duration of 40 days.

- The HMS *Challenger* Expedition included 225 ship's crew and six scientists; the Lewis and Clark Expedition included 51 men, plus guide and translator Sacagawea; the *Okeanos Explorer* includes berthing for 46 crew and mission support personnel.

- The HMS *Challenger* Expedition sailed 68,890 nautical miles, entering all oceans but the Arctic; the Lewis and Clark Expedition covered 3,700 miles paddling, walking and riding on horseback; the *Okeanos Explorer* may operate anywhere in Earth's ocean that is free of ice.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics" in the menu on the left side of the page, then "Human Activities" then click on "Maritime Heritage" for activities and links about the HMS *Challenger* and other ocean exploration expeditions.

The "Me" Connection

Have students write a brief essay discussing how they use (or might use) anomalies to explore an unfamiliar area.

Connections to Other Subjects

English/Language Arts, Social Studies

Assessment

Answers to *Inquiry Guide* questions and class discussions provide opportunities for assessment.

Extensions

1. Visit http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html for the latest activities and discoveries by the INDEX/SATAL 2010 Expedition.

2. Visit http://oceanexplorer.noaa.gov/explorations/lewis_clark01/lewis_clark01.html and http://oceanexplorer.noaa.gov/explorations/03mountains/background/challenger/challenger.html for more information about connections between modern ocean exploration and the Lewis and Clark and HMS *Challenger* Expeditions.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

Calling All Explorers . . .
(14 pages, 124k) (from the 2002 Submarine Ring of Fire Expedition)
http://oceanexplorer.noaa.gov/explorations/02fire/background/education/media/ring_calling_explorers_9_12.pdf

Focus: Recent explorers of deep-sea environments and the relationship between science and history (Ocean Exploration)

Students will learn what it means to be an explorer, both modern and historic; recognize that not all exploration occurs on land; understand the importance of curiosity, exploration, and the ability to document what one studies; gain insight into the vastness of unexplored places in the deep sea; and gain appreciation of science mentors and role models.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html – Web site for the INDEX/SATAL 2010 Expedition, with links to lesson plans, career connections, and other resources http://oceanexplorer.noaa.gov/okeanos/edu/welcome.html – Web page for the NOAA Ship *Okeanos Explorer* Education Materials Collection

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book - A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

http://www.aquarium.ucsd.edu/Education/Learning_Resources/Challenger/science2.php – Virtual exhibit about HMS *Challenger* on the Scripps Institution of Oceanography Birch Museum Web site

http://oceanexplorer.noaa.gov/explorations/lewis_clark01/lewis_clark01.html – Web page for the 2001 Lewis and Clark Legacy Expedition

http://www.monticello.org/jefferson/lewisandclark/index.html – "Jefferson's West" from the Jefferson Monticello Web site

http://oceanexplorer.noaa.gov/explorations/03mountains/background/challenger/challenger.html – "Then and Now: The HMS *Challenger* Expedition and the 'Mountains in the Sea' Expedition"

http://explore.noaa.gov/special-projects/indonesia-u-s-scientific-and-technical-cooperation-in-ocean-exploration/files/Okeanos_Explorer_for_WOC_-_FINAL.pdf – NOAA Fact Sheet about the NOAA Ship *Okeanos Explorer*

National Science Education Standards

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

Content Standard E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science
- Science as a human endeavor
- Historical perspectives

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.
Fundamental Concept a. The ocean is the dominant physical feature on our planet Earth— covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian and Arctic.

Essential Principle 4.
The ocean makes Earth habitable.
Fundamental Concept b. The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.
The ocean and humans are inextricably interconnected.
Fundamental Concept a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.
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.

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 c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.
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.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
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Exploring the Unknown
Exploration Strategies Inquiry Guide

Part 1: Lessons from Previous Voyages of Discovery

Two of the most famous expeditions to explore unknown territory are the Lewis and Clark Expedition and the *Challenger* Expedition. Both of these expeditions are generally considered to have been successful, and produced a great deal of information that provided vital guidance for subsequent explorations and scientific studies. Exploration strategies used by these expeditions may offer some useful ideas for modern-day voyages of discovery. The following questions will help guide your inquiry into these strategies.

1. Exploration strategies usually are strongly influenced by the underlying purpose of the expedition. What was the overall mission of the expedition?

2. What was the overall plan for the expedition's route?

3. What scientific measurements or observations did the expedition make?

4. What technical instruments did the expedition have available?

5. How long was the expedition?

6. How many people were involved in the expedition?

7. How much area did the expedition cover?

Part 2: NOAA Ship *Okeanos Explorer*

In 2000, the President's Panel for Ocean Exploration issued its report, "Discovering Earth's Final Frontier" (http://oceanservice.noaa.gov/websites/retiredsites/supp_oceanpanel.html). The report calls for a new national Ocean Exploration Program, noting that previous efforts to explore the ocean had "ended before a significant portion of the ocean was visited in even a cursory sense; and 2) Marvelous new tools now exist that permit exploration in spatial and temporal dimensions that were unachievable 50 years ago. For these reasons, we must go where no one has ever gone before, 'see' the oceans through a new set of technological 'eyes,' and record these journeys for posterity."

In August 2008, the NOAA Ship *Okeanos Explorer* was commissioned as the only U.S. ship whose sole mission is to systematically explore our largely unknown ocean for the purposes of discovery and the advancement of knowledge. List some ideas for exploration strategies that could be used to fulfill this mission. In particular, consider:

- What kind of measurements or observations should be made?
- What technologies could be used to make these measurements or observations?