Principle 7: The ocean is largely unexplored.

People Explore the Ocean — A

Exploration leads to a better understanding of ocean systems.

A1
There are many opportunities for ocean exploration, which can lead to hypothesis-generated science.

A2
Since 1970, the use of ocean resources has increased significantly. The sustainability of ocean resources therefore depends on our understanding of the potential and limitations of those resources

A3
New methods and technologies are being developed to utilize the ocean for mineral and biological resources, and as a source of energy (e.g., tidal power, wave power, and ocean thermal energy conversion).

A4
Data gathered from advanced technology enable scientists to make better estimations and predictions of physical and biological phenomena.

A5
Looking at data over time allows us to better understand the complexity and changing patterns in the ocean (e.g., noise pollution, weather, sea surface temperatures, and dead zones).

A6
New habitats and species continue to be discovered throughout the ocean.

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A7
Current exploration of ocean organisms is leading to new discoveries for human health and our interconnectedness to the ocean.

A8
There are many ways that humans benefit from discoveries about the ocean (e.g., cancer research, new medicines, energy, etc.).

A9
There are many ways that human activities negatively impact the ocean that are not fully understood.

Ocean Exploration Requires Collaboration — B

Ocean exploration involves collaboration of people in different careers, disciplines, countries, and organizations, which include universities, research Institutes, government agencies, and private industries.

B1
People in different countries with knowledge and skills in a diverse range of careers and disciplines propose ideas and develop methods for exploring and understanding the ocean.

B2
Careers in ocean exploration require personal interest and commitment, and years of study and apprenticeships, which may include education and training in vocational schools, colleges, and/or universities.

B3
The communication of accurate and timely information allows the public to make informed decisions that promote sustainability of the ocean.

B4
Understanding the ocean requires the use of data and technologies from many domains of knowledge, such as computer science, engineering, biology, geology, chemistry, and physics.

B3
The communication of accurate and timely information allows the public to make informed decisions that promote sustainability of the ocean.

B5
Political, social, and scientific engagement on both national and international levels can affect the opportunity for, awareness of, and future directions of ocean exploration.

B3
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B6
Exploring the ocean involves global participation because there is only one ocean that connects and sustains all life.

Ocean Exploration Requires Technological Innovations — C

The ocean covers 70% of Earth, but less than 20% of it has been mapped, observed, and explored. This is due to extreme physical properties of the ocean that make exploration difficult, e.g., temperature, light, salinity, depth, vastness, and pressure. The ability to explore and observe the ocean depends on the development and use of new technologies, all of which have strengths and limitations.

C1
Scientific models and simulations are used to describe, manipulate, and experiment with ocean systems, in order to better understand these systems and their interactions, interconnections, and interdependence.

C2
Scientific models are physical, mathematical, or logical representations of entities, processes, and phenomena that make them comprehendible (e.g., computer rendering of ocean circulation patterns).

C3
Scientific models are limited by the accuracy of their representation of the complexity of ocean systems, which in turn is limited by: our scientific knowledge of the systems; our ability to transform our knowledge into accurate mathematical equations; our ability to collect sufficient types and quantity of data over time and geographic locations; and the power of computers to use these data to recreate the systems and make calculations and simulations.

C4
Advances in technology, such as satellites, sea floor and sea surface observatories, and digital media, have facilitated improvements in scientific models and simulations because they offer scientists extensive real-time data over time and space.

C5
Simulations are the implementation of these models over time to test, analyze, and experiment with the representations of these real-world ocean systems.

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C4
Advances in technology, such as satellites, sea floor and sea surface observatories, and digital media, have facilitated improvements in scientific models and simulations because they offer scientists extensive real-time data over time and space.

C6
Tools and technologies have been developed and deployed both in outer and inner space to collect a wide variety of data from ocean systems over time and geographic location.

C7
Submersibles allow scientists to observe and collect data below the ocean's surface. These include Human-Occupied Vehicles (HOVs), Remotely-Operated Vehicles (ROVs), and Autonomous Underwater Vehicles (AUVs).

C8
HOVs allow scientists to go down to great depths to observe and collect samples. HOVs are compact and dependent on surface-support vessels.

C9
Groundbreaking research, such as the discovery of life at hydrothermal vents, has been done in HOVs. However, they are not capable of reaching the deepest regions in the ocean, are costly to operate, and lack the versatility and endurance of ROVs and AUVs.

C10
ROVs are underwater robots tethered (i.e., linked by a cable) to a ship and operated by a pilot on that ship. The cables carry electrical power, video, and other data signals back and forth between the pilot and the vehicle.

C11
ROVs can be outfitted with additional sensors and equipment, such as sonars, magnetometers, robotic arms and water samplers, so scientists can collect data and specimens, and conduct experiments deep under the surface of the ocean.

C12
AUVs are undersea computer- controlled systems. There is no physical connection to their operator, who may be onshore or aboard a ship. They are self-guiding and self-powered, are safe from bad weather, and can reach shallower water than boats and deeper water than human divers or ROVs.

C13
AUVS can be outfitted with oceanographic sensors to measure numerous physical and biological features of the ocean. The geographic coverage and length of deployment time to collect data by AUVs is not limited by a cable or human occupant.

C14
Scientists and natural resource managers use this data to understand the ocean and climate processes, as well as to monitor water quality and other activity around protected areas.

C15
Satellites collect and transmit largescale, continuous data from sensors (e.g., satellite imagery), or transmitters on buoys placed in fixed locations in the ocean, or on AUVs and living organisms that move throughout the ocean.

C16
Scientists, and citizens alike, use satellite data from buoys in fixed locations to obtain information about local and regional places to understand daily, seasonal or annual patterns of change at these locations.

C17
AUVs, such as gliders, can be programmed to collect data from specific depths along pre-determined paths. Satellites receive the data from the AUVs to obtain information about the ocean surface and water column for a geographic region.

C18
Satellite data from living organisms (e.g., from transmitters attached to elephant seals, tuna, and/or sea turtles) provide information such as where these organisms travel. Scientists use this data to understand the geographic range and distribution, habitats, and migratory patterns of these organisms.

C19
Satellites with cameras and radiometers provide extensive images of the ocean surface. For example, data from NOAA and NASA satellites are used to map sea surface temperatures and productivity.

C20
Ocean-observing systems (OOS) are newer approaches to studying the ocean. They provide scientists with extensive and continuous data about the Earth, ocean, and atmosphere, so they can investigate the interactions and interconnections of ocean and climate processes, and the impacts from human activities.

C21
An OOS employs both remote and in situ sensing methods to gather data. Remote sensing includes satellite-, aircraft- and land-based sensors, power sources, and transmitters. In situ sensing includes platforms (ships, buoys, gliders), sampling devices, power sources, and transmitters. These devices and sensors collect a variety of data, such as salinity, sea surface temperature, and cloud cover, which are transmitted to computers in labs onshore.

C22
Advancements in technology to conduct molecular analysis (e.g., DNA technology and Isotope analysis) provide scientists with more detailed Information on organisms in large-scale systems (e.g., population structures, food webs, and migrations).