GRADE 5 UNIT 3 OVERVIEW

Climate Change

Introduction

Climate describes the long-term average of conditions in the atmosphere and ocean at the same geographic locations over long periods of time. The Earth's tilt and its rotation around the sun, volcanic eruptions, the chemical composition of the atmosphere, and large-scale global patterns of the transfer of heat energy from the sun play significant roles in defining area climates.

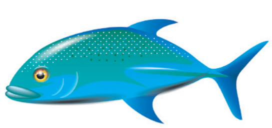
Before understanding climate, one must understand day-to-day weather. In Lesson 1, students think about and describe their local weather and Hawai'i's climate. They imagine a conversation with friends planning their first trip to the islands and wanting to know about Hawai'i's weather and climate and ultimately discuss how weather and climate influence the way people live in Hawai'i. Additionally, students will observe how the Earth's rotation and tilt on its axis cause day and night while influencing seasonal changes.

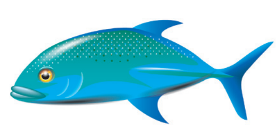
Students then measure and keep records of daily temperatures and rainfall, and make short-term weather predictions that they contrast with official daily weather reports. After this, students study the tools scientists use to compile weather data and make weather and climate predictions.

Students will learn about the Earth's atmosphere, comprised of gases called greenhouse gases and how solar radiation is reflected, refracted and absorbed by the greenhouse gases. They are presented with information that shows the level of greenhouse gas carbon dioxide has been increasing significantly over the past 50 years and what that means to the environment and climate. They explore ways that scientists look at what the Earth's climate was millions of years ago. The Earth has several natural "recording devices," such as ice cores, glaciers, tree rings and coral reef cores, that can indicate both what the climate was like eons ago and how it has changed.

There are a wide variety of factors that influence climate and various natural phenomenon scientists monitor to determine if and how our climate is changing. Through a guided categorizing and matching activity, students discuss these factors and are guided to understand that many natural events on a global scale indicate climate.

In a lab experiment, students build a model of an island in containers and note the effect of rising water on their model. Students look at computer-generated models of potential climate change that have been created by scientists to help predict future climate. Should current climate predictions come true, these computer-generated models help students visually experience the impact of potential changes in climate over the next century.





At A Glance

Each Lesson addresses HCPS III Benchmarks. The Lessons provide an opportunity for students to move toward mastery of the indicated benchmarks.

ESSENTIAL QUESTIONS	HCPS III BENCHMARKS	LESSON, *Brief Summary,* Duration
How do scientists distinguish the difference between weather and climate? Why is Hawai'i's climate different from the climate of other locations? What are the factors that cause seasonal change? Why is it important to control variables in a scientific investigation? How do models and simulations teach us about features, objects, events and processes in the real world?	Science Strand 1:Scientific Process: Scientific Investigation: SC 5.1.1: I can identify the variables in scientific investigations and recognize the importance of controlling variables in scientific experiments Science Strand 2: The Scientific Process: Nature of Science: SC 5.2.1: Use models and/or simulations to represent and investigate features of objects, events and processes in the real world. Science Strand 8: Physical, Earth and Space Sciences: SC 5.8.4: Earth in the Solar System: Demonstrate that day and night are caused by the rotation of the Earth on its axis.	**Lesson 1: Describing Hawai'i's Weather and Climate** This first lesson engages students in thinking about, and describing, their local weather and Hawai'i's climate. Using a simulation, students will observe how the Earth's rotation causes day and night, while influencing seasonal changes. Two 60-minute periods

ESSENTIAL QUESTIONS	HCPS III BENCHMARKS	**LESSON,** *Brief Summary,* Duration
How does technology help humans to observe and predict weather and climate? How do models and simulations teach us about features, objects, events and processes in the real world?	Science Strand 2: The Scientific Process: Nature of Science: SC 5.2.1: Use models and/or simulations to represent and investigate features of objects, events and processes in the real world. Math Strand 10: Patterns, Functions and Algebra: MA 5.10.2: Model problem situations with objects or manipulatives and use representations (e.g., graphs, tables, equations) to draw conclusions Language Arts Strand 1: Reading: Conventions and Skills: LA 5.1.2: Locating Sources/Gathering Information: Use a variety of grade–appropriate print and online resources to research a topic. Language Arts Strand 4: Writing: Conventions and Skills: LA 5.4.1: Range of Writing: Write in a variety of grade-appropriate formats for a variety of purposes and audiences, such as note summarizing what they have read or heard.	**Lesson 2: How Can We Predict Weather with Technology?** Students collect data about the weather, including temperature and rainfall. They compare their data with National Weather Service (NWS) daily weather reports, and see how the information compares and contrasts to it. They research tools that NOAA and NWS use to measure and predict weather, and make a prediction of their own. Three 60-minute periods

ESSENTIAL QUESTIONS	HCPS III BENCHMARKS	LESSON, *Brief Summary,* Duration
What evidence is there of historical changes in Hawai'i's climate? How is the atmosphere affected by an abundance of greenhouse gases?	Science Strand 6: Physical , Earth and Space Science: SC 5.6.3 Compare what happens to light when it is reflected, refracted, and absorbed Language Arts Strand 1: Reading: Conventions and Skills: LA 5.1.2: Use a variety of grade–appropriate print and online resources to research a topic. Language Arts Strand 4: Writing: Conventions and Skills: LA 5.4.1: Write in a variety of grade-appropriate formats for a variety of purposes and audiences, such as note summarizing what they have read or heard. Language Arts Strand 6: Oral Communication: LA 5.6.1: Use speaking and listening skills to fill a prescribed role in group activities. LA 5.6.2: Give informal presentations or reports to inform	**Lesson 3: Climate Of Our Past** Students examine the role of greenhouse gases in our atmosphere. Students then look at ways scientists determine what climate was like millions of years ago and if there were historical changes in climate. Students conduct library and online searches to learn about ice cores, tree, rings, coral reef cores, and glaciers; then, develop a class presentation. Two 45-minute periods
How does the melting of glaciers and sea ice affect sea level? How do scientists predict future effects of climate change and its impact on Hawai'i?	Science Strand 1:Scientific Process: Scientific Investigation: SC 5.1.1: I can identify the variables in scientific investigations and recognize the importance of controlling variables in scientific experiments Science Strand 2: The Scientific Process: Nature of Science: SC 5.2.1: Use models and/or simulations to represent and investigate features of objects, events, and processes in the real world.	**Lesson 4: Impacts of Climate Change** Students will create a model and conduct an experiment to determine how the melting of glaciers and sea ice will affect sea level. Students will also examine how computer simulations can analyze and describe the effects of climate change, including predictions of rise in sea levels, increased number and severity of hurricanes, and droughts. This lesson focuses particularly on developing skills in interpreting data from line graphs, bar graphs, and graphic images (all scientific models of data), and using interpretations to draw conclusions. Two 45-minute periods

"Hawaii Content & Performance Standards III Database." Hawaii Department of Education. June 2007. Department of Education. 17 Dec. 2007.

Benchmark Rubric

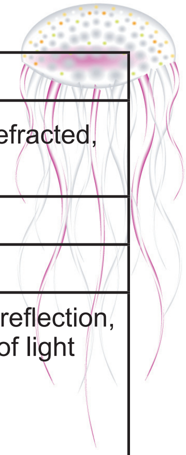
I. HCPS III Benchmarks*

Below is a general Benchmark Rubric. Within each lesson, there are other assessment tools and additional rubrics specific to the performance tasks within each lesson.

Topic		**Scientific Inquiry**	
Benchmark SC.5.1.1		Identify the variables in scientific investigations and recognize the importance of controlling variables in scientific experiments	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Identify the variables in scientific investigations, explain why variables need to be controlled, and give examples of how to control variables in scientific experiments	Identify the variables in scientific investigations and recognize the importance of controlling variables in scientific experiments	Identify, with assistance, the variables in a scientific investigation or the importance of controlling the variables	Recognize, with much assistance, the variables in scientific investigations

Topic		**Scientific Inquiry**	
Benchmark SC.5.1.2		Formulate and defend conclusions based on evidence	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Formulate and defend conclusions that are supported by detailed evidence and make connections to the real world	Formulate and defend conclusions that are supported by evidence	Make conclusions that are partially supported by evidence	Make conclusions without evidence

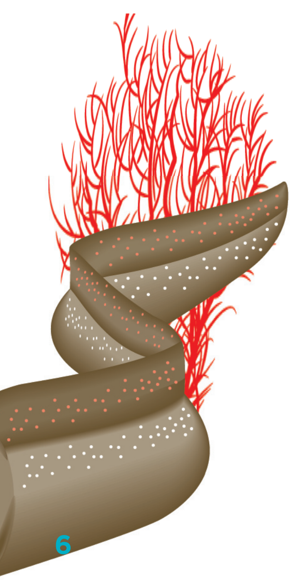
Topic		**Unifying Concepts and Themes**	
Benchmark SC.5.2.1		Use models and/or simulations to represent and investigate features of objects, events, and processes in the real world	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Consistently select and use models and simulations to effectively represent and investigate features of objects, events, and processes in the real world	Use models and/or simulations to represent and investigate features of objects, events, and processes in the real world	With assistance, use models or simulations to represent features of objects, events, or processes in the real world	Recognize examples of models or simulations that can be used to represent features of objects, events, or processes



Topic		Waves	
Benchmark SC.5.6.3		Compare what happens to light when it is reflected, refracted, and absorbed	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Compare and give examples of the ways light can be reflected, refracted, and absorbed	Compare what happens to light when it is reflected, refracted, and absorbed	Describe that light is reflected, refracted, and absorbed	Provide examples of the reflection, refraction, or absorption of light

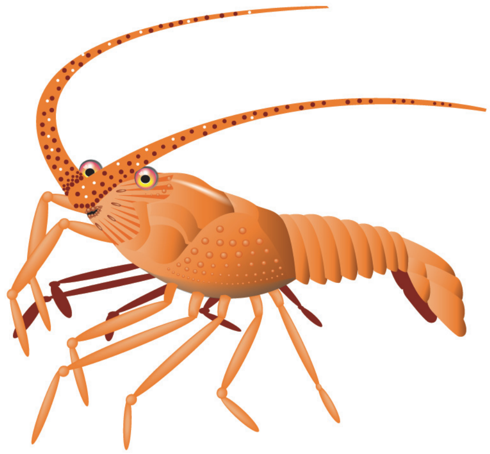
Topic		Earth in the Solar System	
Benchmark SC.5.8.4		Demonstrate that day and night are caused by the rotation of the Earth on its axis	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Use a model to demonstrate and explain how the rotation of the Earth on its axis causes day and night	Demonstrate the rotation of the Earth on its axis and how it causes day and night	Provide an example that the Earth rotates on its axis and causes day and night	Recognize that the Earth rotates on its axis and causes day and night

Topic		Numeric and Algebraic Representations	
Benchmark MA.5.10.2		Model problem situations with objects or manipulatives and use representations (e.g., graphs, tables, equations) to draw conclusions	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Model problem situations with objects or manipulatives and use representations to draw conclusions, with accuracy	Model problem situations with objects or manipulatives and use representations to draw conclusions, with no significant errors	Model problem situations with objects or manipulatives and use representations to draw conclusions, with a few significant errors	Model problem situations with objects or manipulatives and use representations to draw conclusions, with many significant errors



Topic		Probability	
Benchmark MA.5.14.1		Use fractions, decimals, and percents to indicate the probability of events	
Rubric			
Advanced	Proficient	Partially Proficient	Novice
Use fractions, decimals, and percents to indicate the probability of events, with accuracy	Use fractions, decimals, and percents to indicate the probability of events, with no significant errors	Use fractions, decimals, and percents to indicate the probability of events, with a few significant errors	Use fractions, decimals, and percents to indicate the probability of events, with many significant errors

Topic		Locating Sources/ Gathering Information	
Benchmark LA.5.1.2		Use a variety of grade-appropriate print and online resources to research a topic	
Rubric			
Advanced	Proficient	Partially Proficient	Novice
Use substantive information from an extensive variety of grade-appropriate print and online resources to thoroughly research a topic	Use relevant information from a variety of grade-appropriate print and online resources to research a topic	Use some relevant information from a few grade-appropriate print and online resources to research a topic	Use very little relevant information from grade-appropriate print and online resources to research a topic
Topic		Range of Writing	
Benchmark LA.5.4.1		Write in a variety of grade-appropriate formats for a variety of purposes and audiences.	
Rubric			
Advanced	Proficient	Partially Proficient	Novice
Insightfully adapt writing to grade-appropriate formats for a variety of purposes and audiences	Adapt writing to grade-appropriate formats for a variety of purposes and audiences	Write with some adaptation to grade- appropriate formats for a variety of purposes and audiences	Write with little adaptation to grade-appropriate formats for a variety of purposes and audiences



Topic	Discussion and Presentation		
Benchmark LA.5.6.1	Use speaking and listening skills to fill a prescribed role in group activities		
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Use speaking and listening skills to fill a prescribed role in group activities, in a highly effective way	Use speaking and listening skills to fill a prescribed role in group activities	Use some speaking and listening skills that assist in filling a prescribed role in group activities, in a limited way	Use irrelevant speaking and listening skills that do not relate to a prescribed role in group activities

Topic	Discussion and Presentation		
Benchmark LA.5.6.2	Give informal presentations or reports to inform		
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Give highly effective informal presentations or reports that clearly inform	Give effective informal presentations or reports to inform	Give marginal informal presentations or reports that somewhat inform	Give ineffective informal presentations or reports that do not inform

**HCPS III Benchmarks are from the Hawai'i Department of Education's Website:*
http://doe.k12.hi.us/standards/index.htm.

II. General Learner Outcomes*

Below is a list of the HIDOE General Learner Outcomes (GLOs). Each Unit of the Lessons from the Sea Curriculum addresses the GLOs. Within some lessons, there is more specific mention of individual GLOs with specific pertinence.

I. Self-directed Learner (The ability to be responsible for one's own learning.).

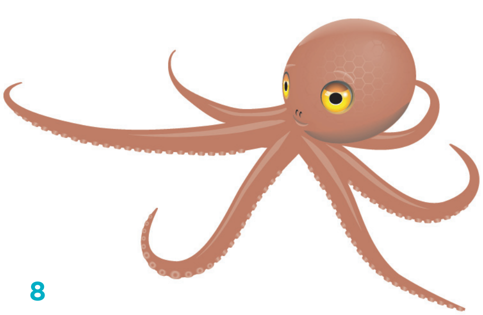
II. Community Contributor (The understanding that it is essential for human beings to work together.).

III. Complex Thinker (The ability to demonstrate critical thinking and problem solving.).

IV. Quality Producer (The ability to recognize and produce quality performance and quality products.).

V. Effective Communicator (The ability to communicate effectively.).

VI. Effective and Ethical User of Technology (The ability to use a variety of technologies effectively and ethically.).



Science Background for the Teacher

Note: Bolded words found within this section are defined in the Science Background for the Teacher Glossary. The footnotes refer to the references found in the Science Background for Teacher Bibliography at the end of this section.

What is climate and how does climate differ from weather? What factors affect Earth's climate? (Lesson 1)

To understand **climate**, we must first understand **weather**. Weather is all around us and has a profound influence on our day-to-day lives; it affects how and where we live, what we do each day, what we wear, and what we eat. Weather describes the day-to-day conditions of the **atmosphere** at a particular location. When we talk about the weather, we describe how windy it is, how hot or cool it feels outside, whether it will rain or be sunny, or whether there is fog or clouds present in the atmosphere. The science of weather is called **meteorology**, and *meteorologists* are scientists that study the weather. Meteorologists make weather predictions based on the different interactions that occur between the atmosphere, continents, and large bodies of water (e.g., Pacific Ocean, the Mediterranean Sea or the Great Lakes). These interactions help shape weather and ,ultimately, influence climate.

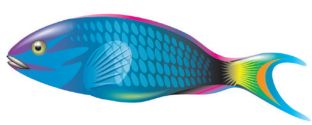
Climate describes the general weather conditions typically found in a particular place *over time*. While weather varies from day-to-day at any particular location, over the years, the same type of weather patterns generally re-occur. This recurring weather pattern for each location is known as the *climate* for that location. Therefore, the climate is the common, average weather conditions at a particular place over a long period of time. The science of climate study is termed **climatology** and *climatologists* are the scientists that study climate. Unlike meteorologists, climatologists look mainly at temperatures and precipitation records spanning at least 30 years. The Köppen climate classification system divides Earth's climates into five general categories and many sub-categories based primarily on temperature and precipitation records. Factors responsible for different climates include the Earth's tilt and its rotation around the sun, volcanic eruptions, the chemical composition of the atmosphere, as well as large-scale global patterns of the transfer of heat energy from the sun. Water movement between the atmosphere, oceans, and continents described by the hydrologic cycle, or *water cycle*, also affect climate. The water cycle is the continuous recycling of water on Earth, from the oceans, up to the atmosphere and down to land, to be transported back to the oceans and atmosphere again.

To see average daily maximum and minimum temperatures as well as precipitation over the last several decades for regions in the USA, go to www.cdc.noaa.gov/USclimate/states.fast.html

To learn more specifically about climate processes on a global scale, go to www.srh.weather.gov/jetstream/matrix.htm

What is the climate of Hawai'i? Describe the events in the atmosphere, ocean, and on land that shape Hawai'i's weather and climate.[2] (Lessons 1 and 2)

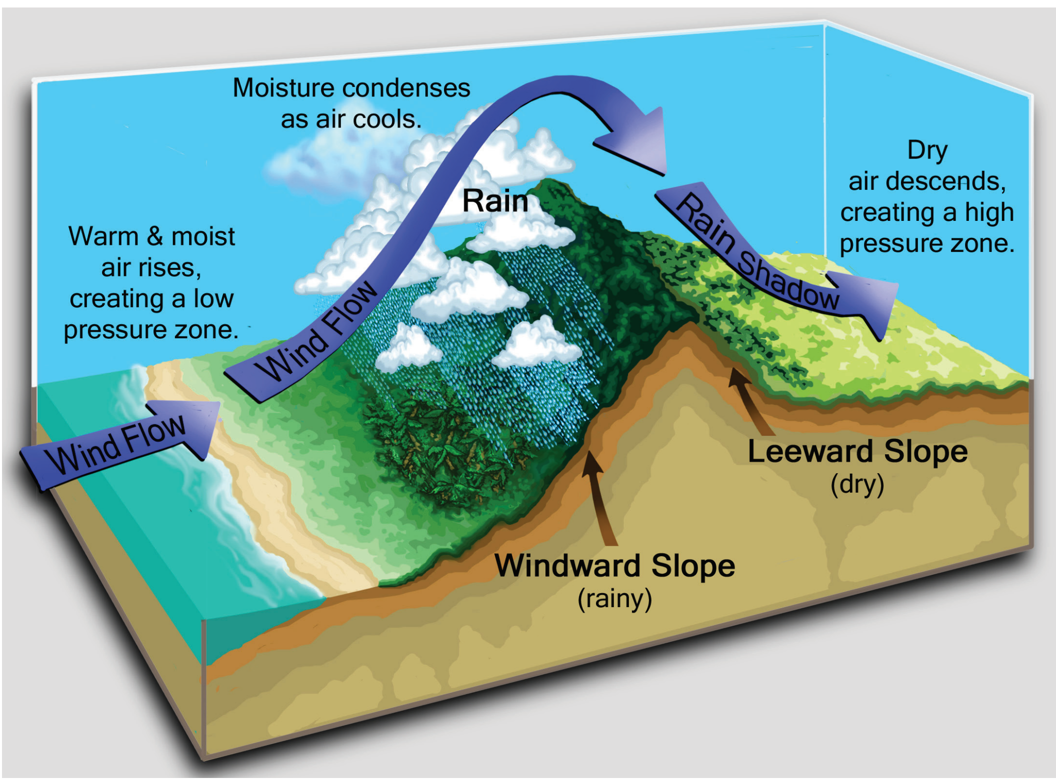
Hawai'i's overall general climate consists of mild temperatures throughout the year, moderate humidity, persistent northeasterly tradewinds, significant differences in rainfall over short distances, and infrequent severe storms. For most of Hawai'i, there are primarily two seasons: summer (dry), between May and October, and winter (wet), between October and April. Hawai'i is within the tropical latitudes, where the length of day and temperature are relatively uniform throughout the year. This results in small seasonal variations in incoming solar radiation and small variations



in temperature. The ocean supplies moisture to the air which acts as a giant thermostat, since its own temperature varies little compared with that of large landmasses. Hawai‘i is more than 2,000 miles from the nearest continental landmass; therefore, air that reaches it spends enough time over the ocean to moderate its initial harsher properties. For example, Arctic air that reaches Hawai‘i during the winter may warm by as much as 100 degrees during its passage over the waters of the North Pacific.

Over the subtropical oceans, atmospheric eddies (areas of circulating air that rarely change position) result in stable weather. One of these, the Pacific High, is usually northeast of Hawai‘i and is responsible for our typical northeasterly tradewinds. The Pacific High follows the seasonal shift of the sun, moving north in summer, and south in winter. The high tends to be stronger and more persistent in summer and weaker in winter. Therefore, in the winter, the tradewinds may be interrupted for days or weeks by the invasion of other fronts or migratory cyclones from the northern latitudes. For example, **Kona storms** are a result of low-pressure systems finding their way to the islands, bringing substantial rain, and halting tradewinds for multiple days.

Hawai‘i’s mountains significantly influence every aspect of its weather and climate. The endless variety of peaks, valleys, ridges, and broad slopes, gives Hawai‘i a climate that is different from the surrounding ocean, as well as a climatic variety within the islands. These climatic differences would not exist if the islands were flat and the same size. Hawai‘i is said to contain up to 13 different climate zones. While average rainfall is between 25 and 30 inches a year near the ocean, the islands receive as much as 15 times that amount in some places and less than one third of it in others. This is caused mainly by the **orographic effect**, when moist tradewind air moves from the sea over the steep and high terrain of the islands, releasing rain. Hawai‘i’s heaviest rains come from winter storms between October and April.



For more information on climate zones in Hawai‘i, go to www.hawaii-forest.com/natural-history/essays/1998-02.asp.

What kinds of technology are used to predict and monitor weather and climate?[6] (Lesson 2)

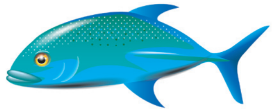
To monitor the weather, meteorologists use many different types of technology. Twice a day, every day of the year, the National Weather Service (NWS) releases **weather balloons** into the atmosphere from various locations around the United States. Weather balloon flights last approximately two hours, and can reach altitudes of 30,000 m (98,425 feet) before bursting. Attached to the weather balloon is an instrument called a **radiosonde** that every 1–2 seconds tracks its location and measures pressure, temperature, and relative humidity. As it ascends into the atmosphere, the weather balloon relays data to tracking systems on the ground. Wind speed and direction are also measured by a parachute attached to the radiosonde so that the radiosonde can be recovered after the balloon bursts. Weather balloons provide valuable input for computer forecast models, local data for meteorologists to make forecasts and predict storms, and data for research. Without them, accurate forecasts beyond a couple of hours would be almost impossible.

Located at over 900 airports nationwide are Automated Surface Observing Systems (ASOS). These unmanned weather stations have numerous sensors that record weather conditions and relay data to the NWS up to 12 times an hour Conditions such as cloud formation and cover, visibility, precipitation, wind speed and direction, and pressure changes are recorded. These ASOS stations are the nation's primary surface weather observation network. For more information on weather balloons and ASOS visit
http://www.srh.noaa.gov/elp/kids/balloon.shtml http://www.srh.weather.gov/jetstream/remote/asos.htm .

Although weather balloons and ASOS stations track weather locally, they are limited in their ability to record weather measurements across vast areas. Remote sensing instruments, such as **Doppler radar** and **satellites**, allow meteorologists to observe weather patterns across larger scales. Doppler radars are used to measure and track precipitation. Radiowaves are sent out into the atmosphere and bounce off particulates such as precipitation. The intensity of reflected radiowaves is measured and converted into weather data that relay the intensity and direction of storms. Satellites are also deployed into space at an altitude that allows them to remain in stationary orbit relative to Earth. This allows satellites to hover continuously over one position on the Earth's surface and to provide constant feedback of changing weather patterns relative to that location by continuously taking images of the atmosphere. For more information on remote weather sensing visit http://www.srh.weather.gov/jetstream/remote/remote_intro.htm .

High-quality marine observations are made using data buoys. NOAA's National Data Buoy Center (NDBC) provides hourly observations from a network of approximately 90 buoys and 60 Coastal Marine Automated Network (C-MAN) stations deployed in surrounding U.S. waters. All stations measure wind speed, direction, and gust, pressure, and air temperature. Additionally, all buoy stations, and some C-MAN stations measure sea surface temperature and wave height and period. Data buoys provide important information about the conditions of the ocean at a fixed spot, such as wind, waves, pressure, and temperature. For information on NOAA's NDBC go to http://www.ndbc.noaa.gov/

Climate models take into account all of the data gathered from the above-mentioned technologies, as well as others, over many years of data collection to gain both physical and behavioral insight into the Earth's climate system, and to produce climate projections. These models use quantitative methods to simulate the interactions of the atmosphere, oceans, land, and ice. There are numerous climate models available that focus on different parts of our Earth's system. The Atmosphere General Circulation Models (AGCMs) couple the atmosphere to the land surface and the cryosphere (portions of the Earth's surface where water is in solid form). The AGCMs also use data of sea-surface temperatures and sea-ice coverage to project the variability of climate and its response to changes in sea-surface temperature over decadal or millennial time periods.



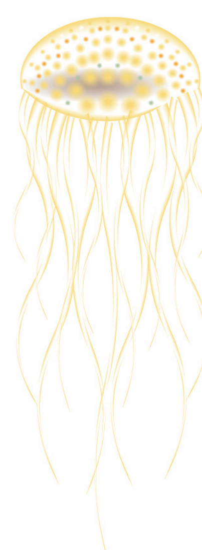
Ocean General Circulation Models (OGCMs) are similar to AGCMs in their scale, but they couple ocean and sea-ice to study ocean circulation patterns. These two overarching models can be coupled with carbon cycle and atmospheric chemistry models to produce the most complex of climate models, Coupled Atmospheric-Ocean General Circulation Models (AOGCMs). These models are used for the prediction and rate of change of future climate. For more information on climate models visit www.metoffice.gov.uk/climatechange/science/projections
or http://news.bbc.co.uk/2/hi/science/natrure/6320515.stm.

What is climate change? What are some major processes that drive climate change?[3]
(Lesson 3 and 4)

The term *climate change* is a broader term for changing conditions throughout the Earth's history. These changes can result from natural events, such as volcanic eruptions, changes in the Earth's orbit, or the amount of energy released from the sun. Human activities are also widely believed to affect the chemical composition of the atmosphere, likely influencing the Earth's climate.

The processes that affect climate differ depending on the time scale. The annual cycle, one full orbit around the sun, is a fundamental force of seasonal climate variations that result from the tilt of the Earth on its axis. This alters the distribution of solar radiation from place to place throughout the year, hence lending itself to the seasons. The most relevant process that affects climate within decadal (10 years) scales is **ENSO (the El Niño Southern Oscillation)** events. ENSOs are inter-annual variations of atmospheric and oceanic conditions in the equatorial Pacific caused by the oceans ability to retain and release heat. **La Niña** events result in eastern tropical Pacific cooling that brings droughts to the southern United States and floods to the Pacific northwestern United States. **El Niño** events result in ocean warming, bringing severe storms to the southwestern United States and monsoon-like conditions to the central Pacific, including Hawai'i. They also result in severe weather conditions around the globe. The oceanic temperature changes that occur with these events have major impacts on migratory bird species and fisheries worldwide. Climatologists have described ENSO events as the largest single source of inter-annual climate variability on a global scale.

The Earth's climate has undergone several Ice Age periods, each spanning approximately 100,000 years, which were a result of elliptical variations in the Earth's orbit around the sun. Over the last 2.6 million years, the Earth has experienced a series of **glacial** and **inter-glacial** periods that cycle every 20,000–40,000 years. These periods are termed Milankovitch Cycles. The most recent Milankovitch Cycle culminated in the Last Glacial Maximum (LGM) some 18,000 years ago, during which ice covered large areas of the Earth. Nearly 32% of the Earth's land area was under ice, and sea level was approximately 120 meters (394 feet) lower than it is today. For a timeline of Earth's climatic history, go to www.ngdc.noaa.gov/paleo/ctl/index.html.



How do scientists study past climate change?[4] (Lessons 3)

Scientists that study past climate change, or **paleoclimatology**, are called *paleoclimatologists*. Paleoclimatology is the study of climate change throughout the entire history of the Earth. Paleoclimatologists construct records of past climate from tree rings, the skeletons of tropical coral reefs, extracted ice cores from glaciers and ice caps, and buried sediments from lakes and oceans. These environmental records are used to estimate past climatic conditions and thus extend our understanding far beyond the 100+ year instrumental record. For example, reef-building corals sequester calcium carbonate from the seawater to build their skeletons (i.e., the reef). The carbonate contains **isotopes** of oxygen, as well as trace metals that can be used to determine the temperature of the water in which the coral grew. These temperature recordings can then be used to reconstruct the climate in which the coral lived in the past. Similarly, tree growth is influenced by climatic conditions. In temperate regions where strong effects of seasonality exist, trees generally produce one ring a year, recording the climatic conditions of each year of growth. Since trees can live hundreds to thousands of years, patterns in tree-ring widths, density, and isotopic composition can reflect variations in climate for centuries to millennia. Located high on the tops of mountains and in polar ice regions, ice has accumulated from snowfall over many millennia. Scientists drill through thick sheets of ice to collect ice cores. These cores contain dust, air bubbles, or isotopes that can be used to interpret the past climate of that area.

What evidence exists for current climate change? What evidence exists in Hawai‘i for climate change?[5] (Lesson 4)

The most significant climate change occurring in modern times is the warming of our Earth by 0.7^{o}C (1.3^{o}F) over the last 100 years, with the four warmest years occurring in the 1990s. Natural influences like periods of increased heat from the sun may have helped make the Earth warmer, but another cause is likely the increase of carbon dioxide into the atmosphere since the start of the **Industrial Revolution** in the 1700s. Carbon dioxide (CO_2) is considered a **greenhouse gas**, a natural component of the chemical composition of the atmosphere that helps the Earth retain heat energy from solar radiation. Without the blanket of greenhouse gases that exist in the atmosphere, our Earth would be on average about 15^{o}C (60^{o}F) cooler, making our climate very different. Since the start of the Industrial Revolution, humans have been increasing the amount of greenhouse gases in the atmosphere by burning fossil fuels and deforestation practices. Ice core records of past climatic CO_2 concentrations are used along with records of atmospheric CO_2 measured from the top of *Mauna Loa* since 1958. The *Keeling Curve*, a graphical representation of CO_2 concentrations in the atmosphere plotted against time, shows that CO_2 has increased over the last millennium from an average of 280 parts per million (ppm) to 400 ppm. Evidence of the Earth's warming can also be found worldwide. For example, many of the world's glaciers are retreating, melting, or shrinking not only in area but also in thickness. In Alaska, an average of 1.8 m (6 ft) of thickness a year is lost, more than twice the annual rate observed from the 1950s to the mid-1990s. Sea level is also rising and over the last hundred years has raised an average of approximately 15 cm (7 in.). Melting glaciers could account for sea level rise, but warmer sea surface temperatures with its associated expansion of warmer water, could also account for sea level rise.

Geological evidence of climates that differ from today is also evident in all the islands by the presence of reef limestone (coral skeleton) found in different regions of the islands, sometimes up to 30 m (98.4 feet) above current sea level. The presence of these coral skeletons indicates higher past stands of the sea associated with interglacial periods around 500,000 years and 125,000 years ago. Terraces and notches cut by shoreline wave action that are inland from today's shorelines also reveal a history of higher sea levels, as well as past lower levels with now submerged notches and terraces. One of the most interesting effects of past lower sea levels was the re-emergence of the island of the Maui Nui, which today exist as the separate islands of *Maui*, *Moloka‘i*, *Lāna‘i*, and *Kaho‘olawe*.

For more information on the coastal geology of the islands visit www.soest.hawaii.edu/coasts/

What are the predicted effects of current climate change? How can climate change impact Hawai'i and other Pacific Islands?[7] (Lesson 4)

The predicted effects of current climate change vary depending on location and, as a result, will have varying effects on the human population and ecosystems. In general, scientists belonging to the International Panel on Climate Change (IPCC), as well as the United Nations Environment Programme, the Intergovernmental Oceanographic Commission and the World Meteorological Organization all conclude global climate change is expected to lead to the following changes of our Earth's weather and climate patterns over the next century: increased air and sea temperatures, rises in sea level, changes in weather patterns, more frequent storms, droughts, floods, and other extreme weather in some places, and changes in the seawater chemistry due to increased carbon dioxide concentrations.

The most immediate change threatening Hawai'i and other Pacific Islands will no doubt be a result of sea level rise. Recent IPCC projections are for a sea-level rise of 48 cm (about 1.5 feet) by 2100. Globally, 100,000,000 people live within approximately 1 m (3.3 feet) of present day sea level, including most of Hawai'i's population. Changes in sea level will be felt through increases in intensity and frequency of storm surges, increased erosion, loss of important wetlands and mangroves, impacts on coral reefs, and impacts on human settlements. A reduced availability of fresh water due to seawater intrusion into Hawai'i's coastal freshwater aquifers will severely affect Hawai'i's ability to obtain fresh water. Increased coastal erosion and loss of land will affect not only where people live, but the livelihood of the tourism economy for all Pacific Islands as beaches, like *Waikīkī* in particular, become submerged. A rise in sea-surface temperatures is also predicted to occur. The range of this rise in temperature is debatable, but is currently predicted to be 1.4–5.8°C (2.7-7.7°F). Current coral bleaching episodes result (in part) from a 2°C (3.6°F) increase in summer maximum temperatures in many parts of the world. If sea surface temperatures increased in Hawai'i and other Pacific Islands, bleaching could effectively wipe out all live coral on the reefs. When the coral dies, the reefs won't continue to grow, and all the species that depend on the reef for food and shelter would be displaced and possibly die out, seriously impacting fisheries.

Science Background for the Teacher Glossary

climate: the long-term average of conditions in the atmosphere (weather), ocean, ice sheets on land and sea ice.
climate model: computer based programs that use data compiled from weather instruments and others over many years to project climate patterns into the future; predictions are based on varying certain parameters of the data.
climatology: the study of the climate and climatic processes.
doppler radar: a type of radar that transmits radio waves into the atmosphere to detect and measure precipitation.
ENSO: the El Niño Southern Oscillation; inter-annual variations of either the cooling or heating of East Pacific Ocean surface waters.
El Niño: an ENSO event that results in warmer surface waters in the East Pacific Ocean.
glacial (period): periods in the Earth's history when glaciers were the dominant feature on Earth.
greenhouse gas: atmospheric gases, such as carbon dioxide, water vapor, methane and ozone that absorbs solar radiation and helps warm the Earth.
hydrologic cycle: the continuous recycling of the Earth's water between the oceans, the atmosphere and land.
ice ages: periods in the Earth's history when temperatures were significantly reduced, resulting in the expansion of ice sheets and glaciers on the Earth's surface.

industrial revolution: a major period in human history when agriculture and manufacturing services were greatly enhanced due to the development of power-driven machinery.
inter-glacial (period): periods in between glacial periods when the glaciers and ice sheets covering the Earth receded due to warmer temperatures.
isotopes: an isotope of an element (such as oxygen) is another form of the same element that has a different number of neutrons in the nucleus (giving it a different atomic weight).
Kona storm: winter low-pressure storms that bring steady and at times intense rainfall to Hawai‘i and can last several days.
La Niña: an ENSO event that results in cooler surface waters in the East Pacific Ocean.
meteorology: the scientific study of the weather.
Milankovitch cycles: the cyclical effects of Earth's orbital processes around the sun that influence climate change on large time scales >100,000 years.
orographic effect: weather phenomenon that results from warm moist air being forced upward along mountainous contours where the air cools and releases its moisture in the form of precipitation.
paleoclimatology: the study of climate change through the entire history of the Earth.
radiosonde: an instrument that measures temperature, pressure and humidity while floating in the atmosphere for short time periods.
satellite: an instrument that orbits the Earth and is often used in meteorology to follow weather patterns across large areas of the Earth.
weather: the daily atmospheric conditions at a given location.
weather balloon: a latex balloon that is used to allow radiosondes to travel into the atmosphere for short time periods.

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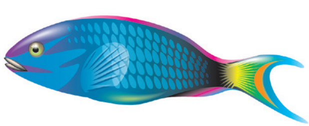

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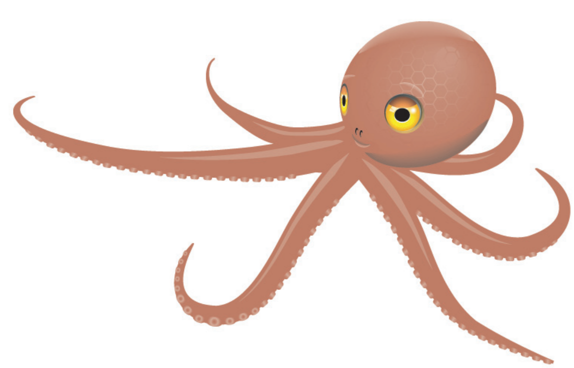


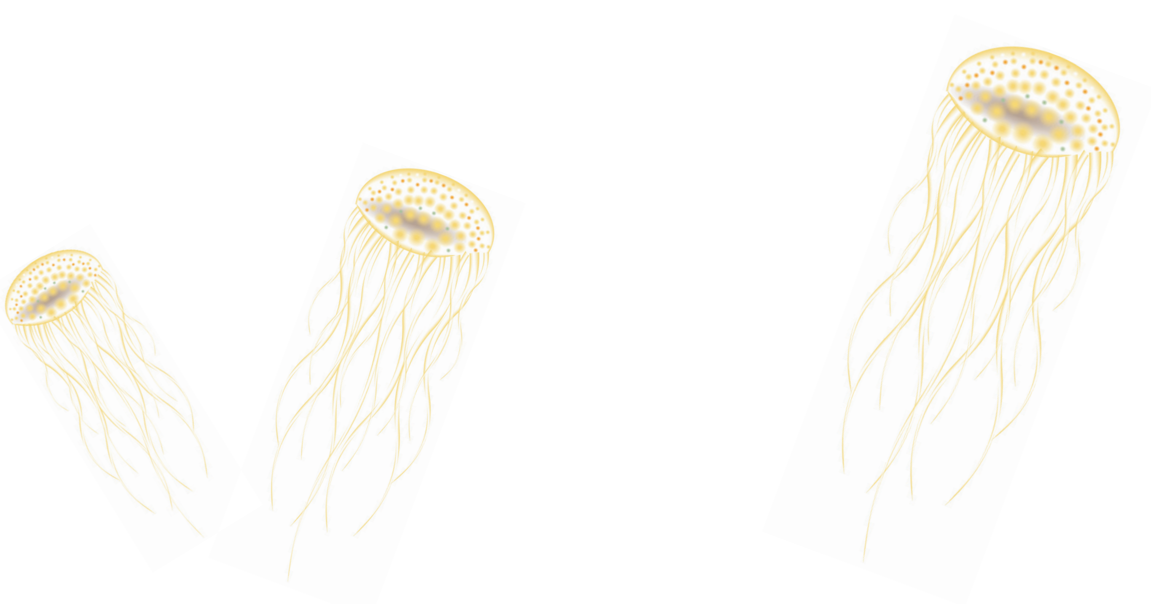
NOAA Resources

Below is a list of resources compiled by the Outreach Education Office of the National Oceanic and Atmospheric Administration. The science standards and the ocean literacy principles addressed in this unit were used as a guideline in selecting the following resources. To access the print resources listed below, contact NOAA's Outreach Education Office directly:

Outreach Unit
NOAA Office of Public and Constituent Affairs
1305 East West Highway #1W514
Silver Spring, MD 20910
Phone: (301) 713-1208
Email: NOAA-OUTREACH@noaa.gov
http://www.education.noaa.gov/

Resources:

- Ocean Service Lesson from Prince William's Oily Mess. "Working with Real Data"
  http://oceanservice.noaa.gov/education/stories/oilymess/working.html
- Ocean Service Fact Sheets – Climate FAQs:
  http://oceanservice.noaa.gov/education/pd/climate/welcome.html
- Climate Change Educator Conference
  http://www.sallyridescience.com/for_educators/conferences/climate/resources
- NOAA National Climatic Data Center Education website
  http://www.ncdc.noaa.gov/oa/edu.html
- NOAA National Climatic Data Center Booklet "TREE RINGS: ANCIENT CHRONICLES OF ENVIRONMENTAL CHANGE"
  http://www.ncdc.noaa.gov/img/edu/Tree_Rings_Booklet.pdf
- http://www.ncdc.noaa.gov/img/edu/El_Nino_Booklet.pdf



OCEAN LITERACY ESSENTIAL PRINCIPLES

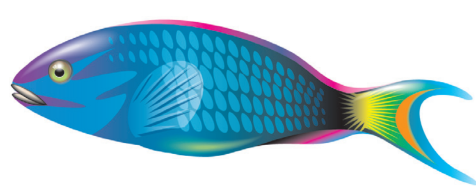
1. The Earth has one big ocean with many features.
   1d. Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools.

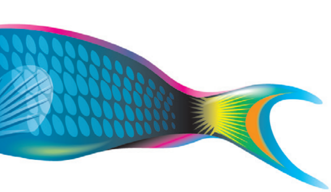
3. The ocean is a major influence on weather and climate.
   3b. The ocean absorbs much of the solar radiation reaching Earth. The ocean loses heat by evaporation. This heat loss drives atmospheric circulation when, after it is released into the atmosphere as water vapor, it condenses and forms rain. Condensation of water evaporated from warm seas provides the energy for hurricanes and cyclones.
   3f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing and moving heat, carbon and water.

6. The ocean and humans are inextricably interconnected.
   6f. Coastal regions are susceptible to natural hazards (tsunamis, hurricanes, cyclones, sea level change and storm surges).

7. The ocean is largely unexplored.
   7d. 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.
   7e. Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems.

Lesson 1: 3b.
Lesson 2: 7d. 7e.
Lesson 3: 1d. 3b. 3f. 6f.
Lesson 4: 1d. 6f. 7e.





CLIMATE LITERACY ESSENTIAL PRINCIPLES

1. The Sun is the primary source of energy for Earth's climate system.
   - 1a. Sunlight reaching the Earth can heat the land, ocean, and atmosphere. Some of that sunlight is reflected back to space by the surface, clouds, or ice. Much of the sunlight that reaches Earth is absorbed and warms the planet.
   - 1c. The tilt of Earth's axis relative to its orbit around the Sun results in predictable changes in the duration of daylight and the amount of sunlight received at any latitude throughout a year. These changes cause the annual cycle of seasons and associated temperature changes.

2. Climate is regulated by complex interactions among components of the Earth system.
   - 2a. Earth's climate is influenced by interactions involving the sun, ocean, atmosphere, clouds, ice, land, and life. Climate varies by region as a result of local differences in these interactions.
   - 2b. Covering 70% of Earth's surface, the ocean exerts a major control on climate by dominating Earth's energy and water cycles. It has the capacity to absorb large amounts of solar energy. Heat and water vapor are redistributed globally through density-driven ocean currents and atmospheric circulation. Changes in ocean circulation caused by tectonic movements or large influxes of fresh water from melting polar ice can lead to significant and even abrupt changes in climate, both locally and on global scales.
   - 2c. The amount of solar energy absorbed or radiated by Earth is modulated by the atmosphere and depends on its composition. Greenhouse gases—such as water vapor, carbon dioxide, and methane—occur naturally in small amounts and absorb and release heat energy more efficiently than abundant atmospheric gases like nitrogen and oxygen. Small increases in carbon dioxide concentration have a large effect on the climate system.

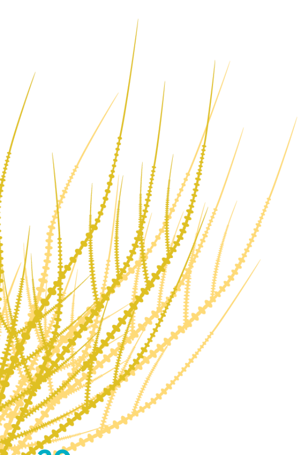
4. Climate varies over space and time through both natural and man-made processes.
   - 4a. Climate is determined by the long-term pattern of temperature and precipitation averages and extremes at a location. Climate descriptions can refer to areas that are local, regional, or global in extent. Climate can be described for different time intervals, such as decades, years, seasons, months, or specific dates of the year.
   - 4b. Climate is not the same thing as weather. Weather is the minute-by-minute variable condition of the atmosphere on a local scale. Climate is a conceptual description of an area's average weather conditions and the extent to which those conditions vary over long time intervals.
   - 4d. Scientific observations indicate that global climate has changed in the past, is changing now, and will change in the future. The magnitude and direction of this change is not the same at all locations on Earth.
   - 4e. Based on evidence from tree rings, other natural records, and scientific observations made around the world, Earth's average temperature is now warmer than it has been for at least the past 1,300 years. Average temperatures have increased markedly in the past 50 years, especially in the North Polar Region.

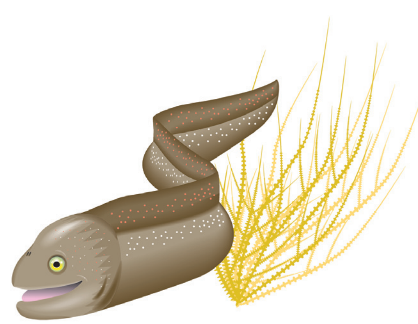
5. Our understanding of the climate system is improved through observations, theoretical studies, and modeling.
   - 5b. Environmental observations are the foundation for understanding the climate system. From the bottom of the ocean to the surface of the sun, instruments on weather stations, buoys, satellites, and other platforms collect climate data. To learn about past climates, scientists use natural records, such as tree rings, ice cores, and sedimentary layers. Historical observations, such as native knowledge and personal journals, also document past climate changes.
   - 5c. Observations, experiments, and theory are used to construct and refine computer models that represent the climate system and make predictions about its future behavior. Results from these models lead to better understanding of the linkages between the atmosphere-ocean system and climate conditions and inspire more observations and experiments. Over time, this iterative process will result in more reliable projections of future climate conditions.

6. Human activities are impacting the climate system.
   6c. Human activities have affected the land, oceans, and atmosphere, and these changes have altered global climate patterns. Burning fossil fuels, releasing chemicals into the atmosphere, reducing the amount of forest cover, and rapid expansion of farming, development, and industrial activities are releasing carbon dioxide into the atmosphere and changing the balance of the climate system.

7. Climate change will have consequences for the Earth system and human lives.
   6a. Melting of ice sheets and glaciers, combined with the thermal expansion of seawater as the oceans warm, is causing sea level to rise. Seawater is beginning to move onto low-lying land and to contaminate coastal fresh water sources and beginning to submerge coastal facilities and barrier islands. Sea-level rise increases the risk of damage to homes and buildings from storm surges such as those that accompany hurricanes.
   6b. Climate plays an important role in the global distribution of freshwater resources. Changing precipitation patterns and temperature conditions will alter the distribution and availability of freshwater resources, reducing reliable access to water for many people and their crops. Winter snowpack and mountain glaciers that provide water for human use are declining as a result of global warming.
   6c. Incidents of extreme weather are projected to increase as a result of climate change. Many locations will see a substantial increase in the number of heat waves they experience per year and a likely decrease in episodes of severe cold. Precipitation events are expected to become less frequent but more intense in many areas, and droughts will be more frequent and severe in areas where average precipitation is projected to decrease.

Lesson 1: 1c. 1d. 2a. 2b. 2c. 4a. 4b. 4c.
Lesson 2: 4b. 5b. 5c.
Lesson 3: 1a. 2a. 2b. 2c. 4a. 4d. 4e. 5b. 6c. 7a.
Lesson 4: 5b. 5c. 7a. 7b. 7c.





Glossary of Cooperative Learning Techniques

In an effort to maximize student engagement and learning, the NOAA Sea Earth and Atmosphere curricular resources were designed using cooperative learning techniques. This guide defines the expectations for implementation of each technique.

What is Cooperative Learning?

Cooperative learning may be broadly defined as any classroom learning situation in which students of all levels of performance work together in structured groups toward a shared or common goal. According to Johnson, Johnson and Holubc, (1994): "Cooperative learning is the instructional use of small groups through which students work together to maximize their own and each other's learning." In classrooms where collaboration is practiced, students pursue learning in groups of varying size: negotiating, initiating, planning and evaluating together. Rather than working as individuals in competition with every other individual in the classroom, students are given the responsibility of creating a learning community where all students participate in significant and meaningful ways. Cooperative learning requires that students work together to achieve goals which they could not achieve individually.

Jigsaw

To Jigsaw materials refers to the use of a strategy in which each student on a team receives only a piece of the material that is to be learned in which that student becomes the "expert." Once the material is learned each member of the team takes a turn teaching the other members their assigned content. This type of dynamic makes the students rely on the other members of their team to learn all of the material.

Think-Pair-Share

This four-step discussion strategy incorporates wait time and aspects of cooperative learning. Students (and teachers) learn to LISTEN while a question is posed, THINK (without raising hands) of a response, PAIR with a neighbor to discuss responses, and SHARE their responses with the whole class. Time limits and transition cues help the discussion move smoothly. Students are able to rehearse responses mentally and verbally, and all students have an opportunity to talk.

Numbered Heads

This structure is useful for quickly reviewing objective material in a fun way. The students in each team are numbered (each team might have 4 students numbered 1, 2, 3, 4). Students coach each other on material to be mastered. Teachers pose a question and call a number. Only the students with that number are eligible to answer and earn points for their team, building both individual accountability and positive interdependence.

KWL Chart

A pre-assessment tool consisting of three vertical columns. Students list what they "Know" about a topic. What they "Want" to know about a topic. The last column students share what they have "Learned" about a topic.

KWL CHART

Be sure to bullet your list.

Use content words only (nouns, verbs, names of people and places, dates, numbers, etc.).

WHAT DO I KNOW?	WHAT DO I WANT TO KNOW? *or* WHAT DO I WANT TO SOLVE?	WHAT HAVE I LEARNED?
•		•

Role Cards

Assign students to cooperative learning groups. Once students are in their groups the teacher will hand out premade role cards that will help each member of the group contribute to the completion of the given task. Before roles are assigned, the teacher should explain and model the task as well as the individual roles for students so that they know and understand how his/her individual role will contribute to the success of the group completing the task. When this technique is used, taking on a different role will aid in student proficiency.

Example of role cards:

Role Card #1

Facilitator:

Makes certain that everyone contributes and keeps the group on task.

Role Card #2

Recorder:

Keeps notes on important thoughts expressed in the group. Writes final summary.

Role Card #3

Reporter:

Shares summary of group with large group. Speaks for the group, not just a personal view.

Role Card #4

Materials Manager:

Picks up, distributes, collects, turns in, or puts away materials. Manages materials in the group during work.

Role Card #5

Time Keeper:

Keeps track of time and reminds groups how much time is left.

Role Card #6

Checker:

Checks for accuracy and clarity of thinking during discussions. May also check written work and keeps track of group point scores.

Round Table

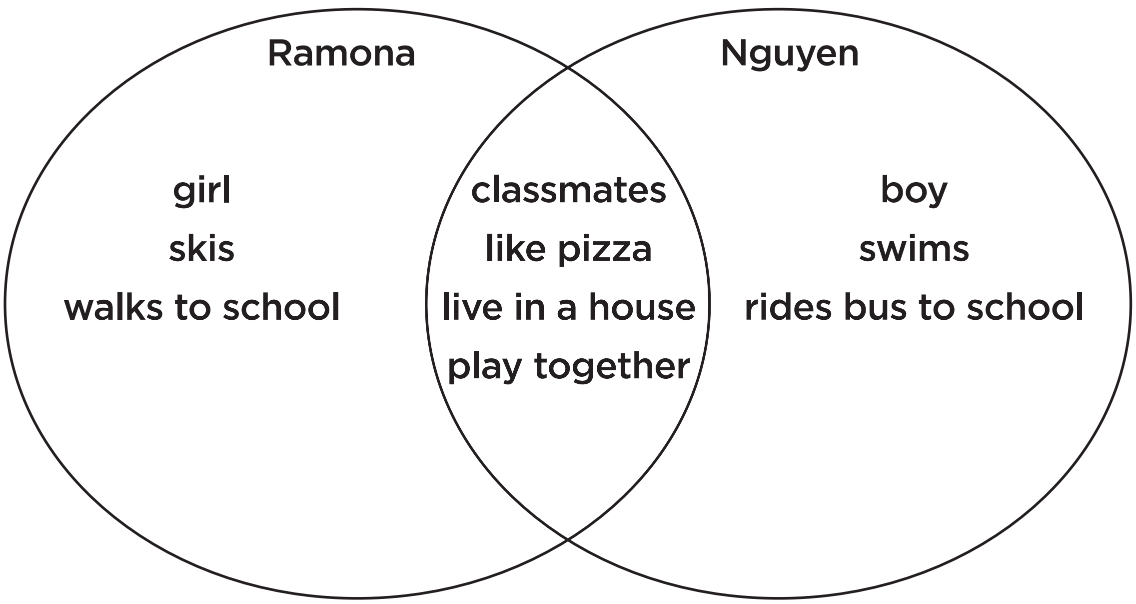
Round table can be used for brainstorming, reviewing, or practicing while also serving as a team builder. Students sit in teams of 3 or more, with one piece of paper and one pencil. The teacher asks a question which has multiple answers. Students take turns writing one answer on the paper, then passing the paper and pencil clockwise to the next person. When time is called, teams with the most correct answers are recognized. Teams reflect on their strategies and consider ways they could improve.

Three-Step Interview

This involves structured group activity with students. Using interviews/listening techniques that have been modeled; one student interviews another about an announced topic. Once time is up, students switch roles as interviewer and interviewee. Pairs then join to form groups of four. Students take turns introducing their pair partners and sharing what the pair partners had to say. This structure can be used as a team builder, and also for opinion questions, predicting, evaluation, sharing book reports, etc.

Venn Diagram

A diagram using circles to represent sets, with the position and overlap of the circles comparing and contrasting the relationships between two given pieces of information.



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