GRADE 4 UNIT 2 OVERVIEW

Weather and Wave Patterns

Introduction

Knowledge about ever-changing weather conditions including temperature, ocean waves, and wave patterns, winds, and wind speeds is particularly important for the safety of Hawai‘i’s residents, and visitors. Weather forecasts keep surfers and other ocean users informed about ideal surfing conditions. They also predict and monitor natural, but destructive events such as tropical storms (hurricanes) and tsunamis, which trigger warnings on radio, TV, newspapers, and websites.

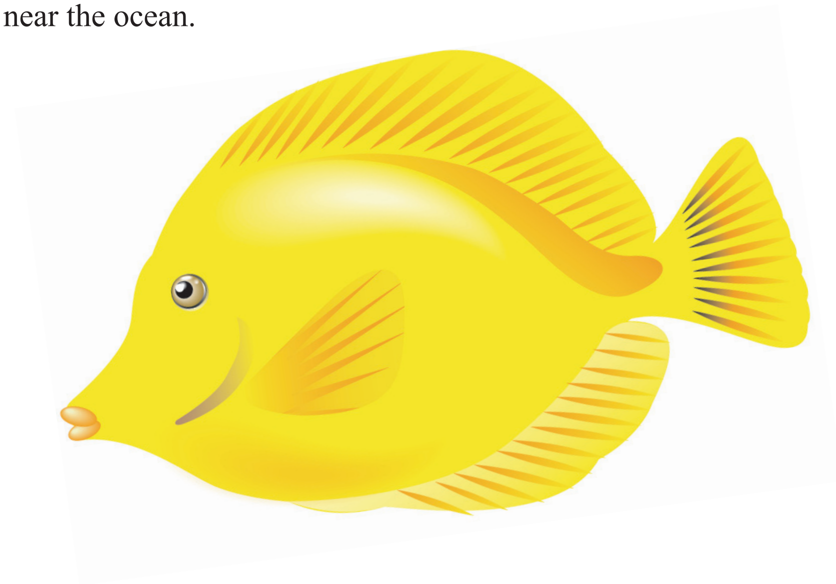
In this unit, students are first introduced to weather forecasting and generate questions about how and why forecasts are made. Students use various media resources to see what is included in weather forecasts and why that information is important.

Students view or download recent online forecast reports and note the information these reports provide. They also investigate data gathering devices (buoys, radars, satellites, and others) used by NOAA and other scientists and organizations to collect weather data and wave measurements, which are transmitted to data centers where the data is used to create accurate computerized weather models.

Through a hands-on activity, students observe and identify waves and other ocean processes, phenomena, conditions, etc. They model waves using tubs of water, and make observations and formulate conclusions about their observations.

Students learn that tsunamis are huge swells triggered by powerful Earthquakes, while hurricanes are formed as winds blow over warm water near the equator for sustained periods of time. They are also reminded that tsunamis and hurricanes can have devastating effects once they make landfall, causing considerable damage, and often resulting in the loss of human lives. Although these natural events cannot be prevented, students learn that organizations such as NOAA use sophisticated technology to monitor these events and warn the public many hours or even days before they strike land. Students are also instructed, based on Internet readings, to create a list of suggestions that the public should follow in case of tsunamis or hurricanes.

In culminating and review exercises, students demonstrate what they learned in this unit by compiling a safety booklet for anyone who lives, works or plays in or near the ocean.



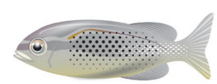
At a Glance

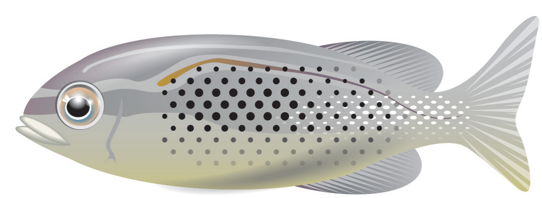
Each Lesson addresses HCPS III Benchmarks.

The Lessons provide an opportunity for students to move toward mastery of the indicated benchmarks.

ESSENTIAL QUESTIONS	HCPSIII BENCHMARKS*	LESSON, Brief Summary, Duration
Why do we want to know the weather? How is weather forecasted?	Science Standard 2: The Scientific Process: SC.4.2.1 Describe how the use of technology has influenced the economy, demography, and environment of Hawai‘i. Language Arts Standard 6: Oral Communications: Conventions and Skills: LA. 4.6.1 Participate in grade-appropriate oral group activities .	**Lesson 1: Why Do We Want to Know?** In this lesson, students brainstorm what should be in a weather forecast. They will get the opportunity to create a forecast of their own. The students will take their created forecast and compare/contrast it with an actual forecast from a media outlet. Students will also discuss how we use components of a weather forecast and some of the technology that makes weather forecasts possible. Two 45-minute periods
What are the origins of surfing and how has it evolved from ancient Hawaiian times to the present? How has technology enabled surfing to evolve over time? How has surfing contributed to the economy of Hawai‘i?	Science Standard 2: The Scientific Process: SC.4.2.1Describe how the use of technology has influenced the economy, demography, and environment of Hawai‘i. Social Studies Standard 3: History: Pre-contact Hawaiian History: SS.4.3.1Explain the origins and culture of early Hawaiians. Language Arts Standard 6: Oral Communications: Conventions and Skills: LA 4.6.2 Give short, informal presentations to inform or persuade	**Optional: Extension Lesson** In this lesson, students track the history of surfing from early documentation of he‘e nalu in ancient Hawai‘i to current times. Students create a storyboard by making drawings that show the evolution of surfing and surfboard design technology. Three 45-minute periods

ESSENTIAL QUESTIONS	HCPSIII BENCHMARKS*	LESSON, Brief Summary, Duration
How does technology enable scientists to predict weather and surf conditions?	Science Standard 2: The Scientific Process: SC.4.2.1 Describe how the use of technology has influenced the economy, demography, and environment of Hawai‘i. Language Arts Standard: Reading: Reading Comprehension: LA. 4.2.5 Summarize main points found in informational texts.	**Lesson 2: How Do We Make Predictions?** This lesson begins by having students revisit the questions they generated in Lesson 1. Students will participate in small group internet research to learn about the buoys and satellites that provide data to the Hawaiian Islands that is used in weather and surf predictions. Two 45-minute periods
What are the characteristics of a wave and how are waves formed? How are an observation and an inference different?	Science Standard 1: The Scientific Process: SC.4.1.2 Differentiate between an observation and an inference. Language Arts Standard 1:Reading: Conventions and Skills: LA. 4.1.1 Use new grade-appropriate vocabulary, including homophones and homographs, learned through reading and word study, including root words, affixes, and word origins.	**Lesson 3: Waves** Using a PowerPoint presentation, the teacher introduces basic information about waves and how they can be described. Students then create a wave box and make observations and inferences about how and why the shape of waves changes with shifts in wind. Students can use these observations to make connections to the type of data that buoys collect. Two 45-minute periods





ESSENTIAL QUESTIONS	HCPSIII BENCHMARKS*	LESSON, Brief Summary, Duration
What is a tsunami? What is a hurricane? How is a tsunami different than big surf or hurricane waves? How are technologies used to detect, measure, and monitor the possibility of a tsunami or a hurricane?	Science Standard 2: The Scientific Process: SC.4.2.1 Describe how the use of technology has influenced the economy, demography, and environment of Hawai'i. Language Arts Standard 1:Reading: Conventions and Skills: LA. 4.1.1 Use new grade-appropriate vocabulary, including homophones and homographs, learned through reading and word study, including root words, affixes, and word origins.	**Lesson 4: Extreme Forecasting** Using a PowerPoint presentation, the teacher introduces the concepts of tsunamis and hurricanes. Students individually complete a worksheet that compares and contrasts the basic characteristics of tsunamis and hurricanes, as well as how technology is used to monitor them. In small groups, students use the Internet to research how technology is used to monitor tsunamis and hurricanes that might affect anyone who lives, works, or plays in or near the ocean in Hawai'i. One 45-minute period
What weather and ocean (i.e., surf) conditions information are essential for public safety? How do weather and surf predictions help the people of Hawai'i? How does technology enable scientists to predict weather and ocean conditions?	Science Standard 1: The Scientific Process: SC.4.1.2 Differentiate between an observation and an inference. Science Standard 2: The Scientific Process: SC.4.2.1 Describe how the use of technology has influenced the economy, demography, and environment of Hawai'i.	**Culminating Lesson: Weather Safety Campaign** Students demonstrate their knowledge of waves and wave size, monitoring, and extreme weather by creating a safety booklet (or other presentation) that warns people of dangerous conditions in both pictures and words. They use both observations from their life experience and the information they have learned in the unit's lessons, and draw inferences. Two 45-minute periods

* *"Hawai'i Content & Performance Standards III Database." Hawai'i Department of Education. June 2007. Department of Education. 17 Dec. 2007.*

Benchmark Rubric

I. HCPS III Benchmarks*

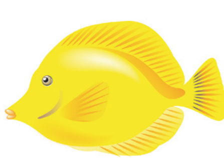
Below is a general Benchmark Rubric. Within each lesson, there are other assessment tools and additional rubrics specific to the performance tasks within each lesson.

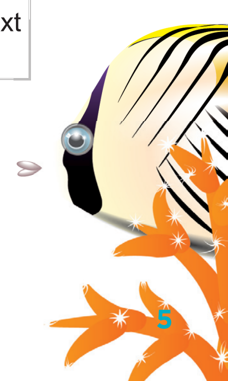
Topic		**Scientific Knowledge**	
Benchmark SC.4.1.2		Differentiate between an observation and an inference	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Explain the difference between an observation and an inference and give examples	Differentiate between an observation and an inference	Provide examples of observations and inferences	Define an observation and an inference

Topic		**Science, Technology, and Society**	
Benchmark SC.4.2.1		Describe how the use of technology has influenced the economy, demography, and environment of Hawai‘i	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Explain how the use of technology has influenced the economy, demography, and environment of Hawai‘i and suggest ways to conserve the environment	Describe how the use of technology has influenced the economy, demography, and environment of Hawai‘i	Give examples of how the use of technology has influenced the economy, demography, and environment of Hawai‘i	Recognize that the use of technology has influenced the economy, demography, and environment of Hawai‘i

Topic		**Vocabulary and Concept Development**	
Benchmark LA.4.1.1		Use new grade-appropriate vocabulary, including homophones and homographs, learned through reading and word study, including root words, affixes, and word origins	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Use new grade-appropriate vocabulary, including homophones and homographs, with fluency, accuracy, and precision	Use new grade-appropriate vocabulary, including homophones and homographs, with no significant errors	Use new grade-appropriate vocabulary, including homophones and homographs, with difficulty and a few significant and/or many minor errors	Use new grade-appropriate vocabulary, including homophones and homographs, with great difficulty and many significant errors or rarely use new vocabulary

Topic		**Constructing Meaning**	
Benchmark LA.4.2.5		Summarize main points found in informational texts	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Summarize the main points and describe their connection to the main idea or focus in informational texts	Summarize the main points found in informational texts	Produce a summary that mixes insignificant points with main points	Summarize information not necessary to understanding the main points of informational texts, or repeat original text rather than summarize





Topic		**Discussion and Presentation**	
Benchmark LA.4.6.1		Participate in grade-appropriate oral group activities	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Participate in grade-appropriate oral group activities, in a highly effective way	Participate in grade-appropriate oral group activities	Participate in grade-appropriate oral group activities, in a limited way or in a way that only partially facilitates the group's work	Participate very little in grade-appropriate oral group activities or participate in a way that does not facilitate the group's work
Topic		**Discussion and Presentation**	
Benchmark LA.4.6.2		Give short, informal presentations to inform or persuade	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Give creative, short, highly effective informal presentations to inform or persuade	Give short, informal presentations to inform or persuade	Give short, informal presentations that are somewhat informative or persuasive	Give short, informal presentations that do not inform or persuade

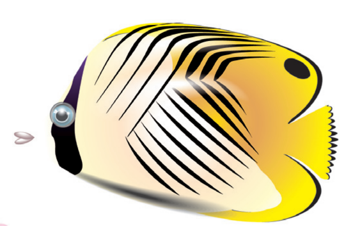
Topic		**Early Hawaiian Society**	
Benchmark SS.4.3.1		Explain the origins and culture of early Hawaiians	
Rubric			
Advanced	**Proficient**	**Partially Proficient**	**Novice**
Explain, with clear and precise detail, the origins and culture of early Hawaiians	Explain, with detail, the origins and culture of early Hawaiians	Explain, with minimal detail, the origins and culture of early Hawaiians	Ineffectively explain the origins and culture of early Hawaiians

II. General Learner Outcomes*

A list of the Hawai‘i Department of Education's General Learner Outcomes (GLOs) follows. 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.)

* *"Hawai‘i Content & Performance Standards III Database." Hawai‘i Department of Education. June 2007. Department of Education. 17 Dec. 2007.*



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 the Teacher- Bibliography* at the end of this section.

What information would be important for surfers? (Lesson 1 and extension lesson)

When a surfer wants to hit the waves, there are many factors they will consider before doing so. The first factor is swell height and direction. Where the swell is originating from and how significant the swell height is, will determine what kind of surf session the experienced surfer will have. Larger swells produce larger waves. Wave forecasts in Hawai'i are communicated on two different scales. The 'Hawaiian scale' measures waves from the still water line to the crest of the wave, this is also referred to as the back of the wave. The 'conventional scale' measures the wave from trough to crest. So when the Hawaiian scale reads 2-4 foot wave heights, the conventional scale will read 4-8 foot wave heights. Knowing the direction of the swell pinpoints which part of the island will be experiencing the best surf. Knowing the swell height will allow a surfer to consider other factors like which surf spot on that side of the island would be best, which board would be most appropriate, etc.

Now that the swell height and direction are known, the next factor to look at would be the tide. Tides are important to look at along with the swell height because that will determine what surf break is best. For example, a small swell on a high tide at a surf break that is in deeper water probably won't be breaking, but a small swell on a high tide at a shallow reef break probably would be breaking. Likewise, a big swell on a shallow reef might close out and be dangerous and un-surfable whereas a big swell on a deeper reef would probably be a lot of fun for an experienced surfer.

One other factor a surfer might look at before jumping in would be the wind. Strong winds can whip water off the tops of the waves, making them harder to surf. Winds can also blow the surfer across the water, making it harder for the surfer to stay in the best position to catch the waves.

To obtain the information described above, many surfers use the internet. Some of the most popular sites to visit include:
http://www.prh.noaa.gov/hnl/pages/SRF.php
http://www.wetsand.com/swellwatch/swellwatch.asp?locationid=2&tabid=1441&subtabid=0&catid=1518&subcatid=1518#anchor1518
http://magicseaweed.com/Hawaii-Surf-Forecast/51/

These sites show wave model data, track storms (storms = surf, usually), and show how current weather conditions, tides, and other pertinent information surfers' use.
Some other info that surfers might want to know about but don't usually seek, is information relating to possible harmful organisms in the water. These include shark sightings, man-o-war and box jellyfish, and harmful algal blooms. For information on these types of threats visit: www.Hawaiibeachsafety.org

What causes waves to come to shore in sets? (Lesson 3)

This is a complicated question to answer and involves an understanding of the physics of waves. So far, we have learned that as wind blows on the surface of the sea for a sustained period of time in a constant direction, energy from the wind will be transferred to the surface of the ocean, thus forming waves. When we think of the energy transferred from the wind, we think of it as a linear process, but in fact as the waves leave the area from which they are formed, they do not stay in a linear formation, they form sets. This is because some of the waves generated are larger and move faster then others, so they tend to group together, thus forming sets!

What causes big waves? (Lesson 3)

Wind is the most common force responsible for the creation of **waves** in the ocean, and it is the wind speed, length of time the wind has blown, and the distance of open water the wind blows over that determines the size of the wave. The greater these three variables are, the larger the waves. Large storm systems often create large waves because of their associated wind speeds and duration.

Waves can be characterized as: **ripples, seas,** or **swells.** When light winds blow across the surface of smooth water, ripples form. If the wind dies, so do the ripples. Seas form when the winds that cause ripples are sustained over a period of time, and they tend to last after the wind has died. Swells are essentially seas that have lasted long after the wind has died. They are waves that have moved away from their origins and are unrelated to local wind conditions.

O‘ahu’s north shore waves (and many other neighbor islands too) are generated by giant winter swells in the North Pacific which then propagate to Hawai‘i. The waves that reach the shore are called **breakers.** Breakers result when the base of the wave can no longer support its top and the wave collapses. This occurs when waves reach the shore as the water becomes shallow, forcing the energy in the wave upwards.

For additional information, see http://www.ndbc.noaa.gov/educate/educate.shtml

What kind of information do buoys provide? (Lessons 2 and 3)

Weather forecasters need frequent, high-quality marine observations for forecast preparation and verification after forecasts are produced. The public relies on these observations and forecasts for commercial and recreational activities such as surfing, canoeing, and boating. 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 located in coastal and offshore waters from the western Atlantic to the Pacific Ocean around Hawai‘i, and from the Bering Sea to the South Pacific. Moored buoy data includes **barometric pressure,** wind direction, speed, and gust, air and sea temperature, and wave height and dominant and average wave period. The direction of wave propagation is also measured on many moored buoys. Data buoys tell us important information about the conditions of the ocean at a fixed spot, such as wind, waves, pressure, and temperature. Forecasters use data from buoys coupled with satellite data to predict weather patterns, marine forecasts, and locate storms and issue warnings. The public uses data from buoys to get information about local marine forecast conditions. For example, surf forecasts are issued daily for each island and give detailed observations about wave height, direction, and period, as well as wind direction and speed, tide heights, and times. Surfers use this information to determine when and where the best places are to surf for a given day. Local surf forecasts can be obtained from http://www.prh.noaa.gov/hnl/pages/marine.php For a map and access to all eleven buoys used in marine forecasts for the Hawaiian Islands, go to http://www.ndbc.noaa.gov/maps/Hawaii.shtml

In addition to their use in operational forecasting and warnings, moored buoy data are used for scientific and research programs, emergency response to chemical spills, legal proceedings, and engineering design. Fisheries scientists often depend on buoy data; for example, sea surface temperature is an important tool to predict seasonal and longitudinal variation in fish distributions. Moored buoys provide valuable data for climate predictions and oceanographic research. The School of Ocean and Earth Science and Technology (SOEST) at the **University of Hawai‘i at Mānoa** employs several data buoys which collect data on a wide range of oceanographic variables. One such project, the Hawai‘i Air Sea Logging Experiment, A Long-Term Oligotrophic Habitat Assesment (HALE ALOHA) buoy has been deployed off the coast of O‘ahu to help ocean scientists develop and test a variety of sensors and data recorders. These sensors allow scientists to study parameters such as oceanic primary productivity, air-sea gas exchange, and temperature fronts, remotely. For additional information on SOEST buoys, see http://hahana.soest.Hawaii.edu/hot/hale-aloha/ha.html
For additional information on NOAA buoys, see http://www.ndbc.noaa.gov/mooredbuoy.shtml
and http://www.bigelow.org/virtual/buoy_sub1.html#instruments

How do hurricanes form? (Lesson 4)

Hurricanes are severe tropical storms that form in the North Atlantic Ocean, the Northeast Pacific Ocean east of the dateline, and the South Pacific Ocean east of 160E longitude. Different names are given to hurricanes depending on where they occur. In the Atlantic and Eastern Pacific Oceans they are called **hurricanes,** in the Western Pacific they are called **typhoons,** and in the Indian Ocean they are called **cyclones.** The scientific term for these severe storms is **tropical cyclone,** and regardless of what they are called or where they occur, all tropical cyclones form in the same way.

Tropical cyclones form over warm ocean water with a temperature of at least 26°C (79°F) near the **equator,** and a depth of 46 m (150 ft). Tropical cyclones grow from the vertical, cyclical movement of air that gains heat and moisture from the surface of the ocean. Warm, **low-pressure** air rises into the **atmosphere,** allowing **new** cooler, dryer **high-pressure** air to sink down and take its place. Wind blowing across the warm ocean causes surface water to **evaporate,** and the **new** air in turn also becomes moist and warm, again causing it to rise into the atmosphere. As warm, moist air rises into the atmosphere it starts to cool, releasing its moisture to form clouds. The cyclic system of air sinking, warming and rising continues and grows, feeding cloud formation and wind. It then starts to spiral away from the equator due to the rotation of the Earth, called the **Coriolis force.** Storms in the northern hemisphere spiral in a counterclockwise direction, and in the southern hemisphere they spiral in a clockwise direction.

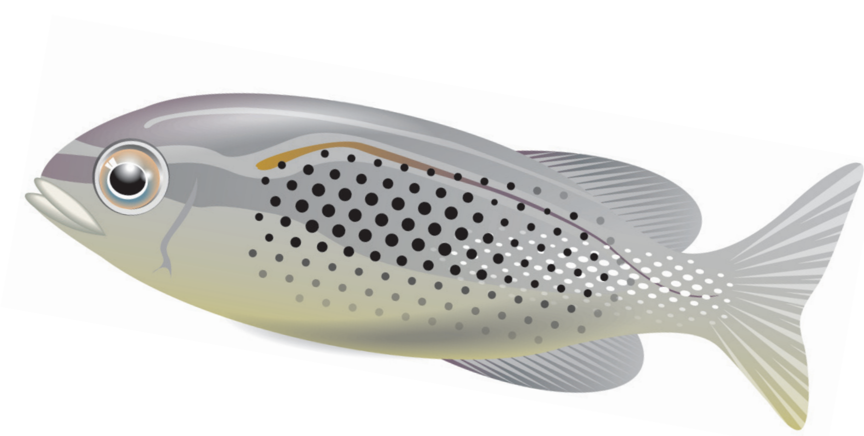
Tropical cyclones that develop into an organized system of clouds with defined circulation and winds of 61 kph (38 mph) or less are considered **tropical depressions.** When wind speeds reach 63 kph (39 mph), they are considered **tropical storms,** and are assigned a name. If wind speeds reach 119 kph (74 mph), they are classified as severe weather systems and considered to be hurricanes, typhoons, or cyclones depending on which ocean they occur.

There are on average six Atlantic hurricanes and nine East Pacific hurricanes each year. These severe storms produce violent winds, waves, torrential rains, and floods. Hurricane categories are assigned to the storms using the **Saffir-Simpson Scale** from 1–5, with 5 being the most severe with maximum sustained winds greater than 249 kph (155mph). As tropical cyclones approach land, their intensity often rapidly decreases because they are no longer being **fed** by the energy from the warm ocean waters. They can still move far inland, dumping many inches of rain and causing wind damage before they die out completely. The category 1 Hurricane *ʻIwa* struck the Hawaiian Islands on November 23, 1982, causing 234 million dollars in property damage, with the island of *Kauaʻi* receiving one-third of the damage. Only ten years later, the category 4 Hurricane Iniki struck the island of *Kauaʻi* on September 11, 1992, with 130 mph winds causing 2.3 billion dollars in property damage. Hurricanes in the Hawaiian Islands are relatively rare events, with Hurricane Hiki being the first recorded hurricane in Hawaiʻi in 1950. Since 1950, five hurricanes have caused serious damage in *Hawaiʻi: Hurricanes Nina, Dot, Estelle, ʻIwa, and Iniki.*

For additional information about hurricanes in Hawaiʻi, see
http://www.soest.Hawaii.edu/MET/Faculty/businger/poster/hurricane/

For general information about hurricanes, visit http://spaceplace.nasa.gov/en/kids/goes/hurricanes/index.shtml

For information on the Saffir-Simpson scale, see http://www.nhc.noaa.gov/aboutsshs.shtml



How are hurricanes tracked? (Lesson 4)

To help predict hurricanes, a variety of technological tools are used to monitor, evaluate, and predict weather disturbances associated with hurricanes, including aircraft, **satellites,** and weather **radar**. The information that is gained from these tools is compiled into computer forecast models which allow forecasters the ability to track and predict the behavior of future storms.

Aircraft operated by NOAA (National Oceanic and Atmospheric Administration) and the U.S. Air Force are used to gather data from around, within, and above hurricanes. These **Hurricane Hunters** are tasked by forecasters at the National Hurricane Center in Miami, Florida to investigate up to three potential hurricanes and typhoons at a time. Sometimes this means they stay airborne for as long as 14 hours. Hurricane Hunters determine the location, wind speeds, size, air pressure, cloud water content, direction, and traveling speeds of hurricanes, and then radio this information back to weather stations as well as the NOAA National Hurricane Center. Other aircraft called **flying laboratories** from NOAA's Miami Aircraft

Operations Center routinely fly into potentially threatening storms and eject radar and sensors into the hurricane to measure a cross-section of the storm, sending back real-time information to weather centers.

Satellites provide informative snapshots of Earth, giving scientists the ability to track variables such as temperature, cloud formation, and other data necessary to understand hurricanes. The National Hurricane Center gets its earliest hurricane warnings from orbiting weather satellites. Satellite pictures show dark clouds moving in spirals, which help spotlight developing hurricanes and their locations. Once they are within 200 miles of a coastal area, hurricanes are monitored by radar. Weather radar allows scientists to measure motion inside storms, recording precipitation intensity and movement, and a variety of wind data. This data provides forecasters with a valuable cross-sectional analysis of a storm. Today, more than 150 WSR-88 Doppler radars monitor weather patterns over the United States and its associated territories.

If a hurricane is expected to come ashore, a hurricane watch is issued for all areas potentially at risk. When the hurricane gets closer to shore, a hurricane warning comes into effect, meaning that the storm may hit within 36 hours. Those in the region are advised to prepare by protecting their homes and their families and maybe even evacuate. The average hurricane warning provides about 35 hours advance notice, but in some cases can be much less (for example, when a hurricane develops quickly close to shore)

Scientists at the National Hurricane Center are constantly analyzing incoming data, in an attempt to estimate when and where the force will strike, how strong it will be, and how long it will last. They do this by combining all of the observational data provided by the above technologies into computer forecast models that allow forecasters to calculate and predict future weather behavior. As more data are collected, forecasters are better able to predict not only the path and strength of current storms, but also seasonal outlooks extending through the entire six-month hurricane season. For additional information on how hurricanes are predicted, see
http://celebrating200years.noaa.gov/magazine/devast_hurricane/welcome.html#intro
http://library.thinkquest.org/C003603/english/hurricanes/prediction.shtml
http://www.nhc.noaa.gov/

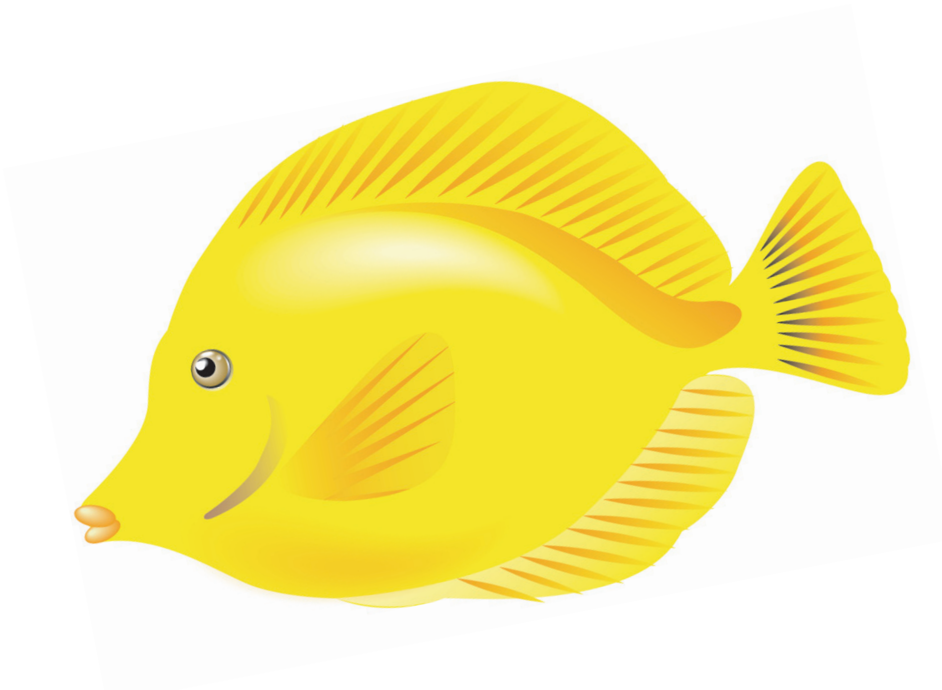
What is a tsunami? (Lesson 4)

Tsunami is a Japanese word meaning **harbor wave. Tsunami** waves are created by any large, abrupt disturbance of the Earth's surface, although they are most often generated by Earthquakes associated with the movement of **tectonic plates** in marine and coastal areas. Underwater landslides, volcanic eruptions, and meteor impacts can also cause tsunamis. If an underwater area of the Earth's crust is suddenly displaced, it can cause a sudden rise or fall in the sea surface above it. Tsunamis are waves with extremely long **wavelengths** of 100 to 200 kilometers (62 to124 miles), and long **wave periods** of 10–20 min. For example, the average depth of the ocean in the Pacific is approximately 4,000 m (13,123 feet) and a typical tsunami has a wavelength of about 150 m (492 feet). When a tsunami leaves its point of origin, it may have a height of 1–2 m (3.28 – 6.56 feet), but this height is distributed over its extremely long wavelength. A vessel in the open ocean may not see the wave, and is in little or no danger if a tsunami passes. As the disturbance travels, the wave's height builds rapidly allowing a tremendous amount of water to race up over the land, causing large water level changes in harbors and river mouths, as well as strong currents. The leading edge of the tsunami wave group may be either a **wave crest** or a **wave trough.**

The Pacific Ocean, ringed by Earthquake fault zones and volcanic activity, is the birthplace of many tsunamis. Activity along the Aleutian Trench produced a tsunami in 1946 that heavily damaged *Hilo, Hawai'i*, killing more than 150 people. In 1957, *Hawai'i* was hit again, but due to early warning and evacuation, no lives were lost. One of the worst disasters caused by a tsunami wave occurred on the morning of December 26, 2004. A magnitude 9.3 Earthquake struck off the Northwest coast of the Indonesian island of Sumatra, altering the ocean floor, pushing the overlying water up into a tsunami wave. As the wave approached land, it reached an estimated height of 25 m (82 ft), flooding the land and killing nearly 300,000 people. The tsunami wave itself also traveled the globe, and was measured in the Pacific and many other places by tide gauges. Sea level measurements in California exceeded 40 cm (15.7in) in height, while New Jersey saw water level fluctuations as great as 34 cm (13.4 in). For additional information, see http://www.tsunami.noaa.gov/

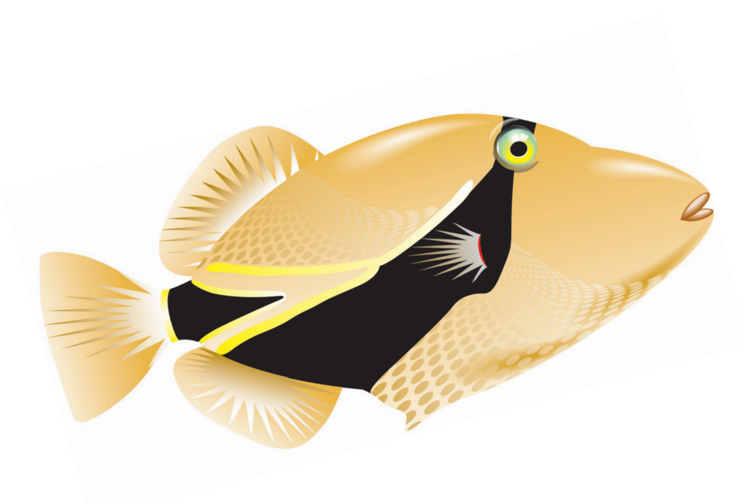
How are tsunamis tracked? (Lesson 4)

Because the characteristics of a tsunami (e.g., wavelength, wave height, and wave direction) are determined by the characteristics of the disturbance (e.g., Earthquake) and each disturbance is unique, forecasting is very difficult. Historically, tsunami warnings were produced by monitoring Earthquake activity and the passage of tsunami waves at tide gauges. However, this system was highly ineffective. Recently developed real-time deep ocean tsunami detectors have greatly advanced NOAA's ability to forecast tsunami events. This system, known as DART (Deep Ocean Assessment and Reporting of Tsunamis) consists of a bottom pressure recorder, a surface buoy, and a satellite that relays the information to monitoring stations. NOAA also operates two tsunami warning centers, the Alaska Tsunami Warning Center (ATWC) in Palmer, Alaska, and the Pacific Tsunami Warning Center (PTWC) in *'Ewa Beach, O'ahu, Hawai'i*. The ATWC serves as the regional warning center the Pacific Northwest, while the PTWC serves as the regional tsunami warning center for *Hawai'i* and as a national/international warning center for tsunamis that pose a Pacific-wide threat. For additional information on tsunamis and forecasting, see: http://www.tsunami.noaa.gov/tsunami_story.html
and http://www.prh.noaa.gov/ptwc/



Science Background for the Teacher Glossary

atmosphere: the layer of gases that surround the Earth.
barometric pressure: a measurement of the 'weight' of the atmosphere.
breakers: waves that collapse when the base of the wave can no longer support the top.
Coriolis force: a force that results from the Earth's rotation deflecting particles (like water or air) to the right in the northern hemisphere, and to the left in the southern hemisphere.
equator: circle of latitude equidistant from the north and south poles that divides the Earth into the northern and southern hemispheres.
evaporation: the process in which the sun heats up water in rivers or lakes or the ocean and turns it into vapor or steam.
fetch: the distance over which wind acts on the water's surface to generate waves.
radar: a device that emits radio waves and translates their reflections to locate or detect objects or surface features.
ripples: waves that form due to light, temporary winds.
Saffir-Simpson Scale: a scale rating hurricanes from 1–5, based on its present intensity, to give an estimate of the potential property damage expected from a hurricane landfall.
satellite: an object in orbit around the Earth or other celestial body.
seas: waves that form when winds are sustained for long periods of time.
storm surge: water that is forced toward the shore by storm winds.
swells: waves that have moved away from their origin after the sustained winds have blown over the ocean surface for long periods of time.
tectonic plates: the dozen or so plates that make up the surface of the Earth.
tropical cyclone: scientific term explaining a strong storm system that forms near the Equator when warm ocean sea surface temperatures combine with winds to create a low pressure system in which the central core is warmer than the surrounding air.
tsunami: Japanese word meaning *harbor wave*, also called seismic sea waves. Tsunamis are waves produced by sudden movements of the Earth's crust, or Earthquakes.
wave: a transfer of energy, progressively from point to point in a medium (in this case water) with speed determined by the properties of the medium.
wave crest: the highest part of a wave.
wavelength: the horizontal distance between two successive wave crests or two successive wave troughs.
wave period: the time required for two successive wave crests or troughs to pass a fixed point.
wave trough: the lowest part of a wave.



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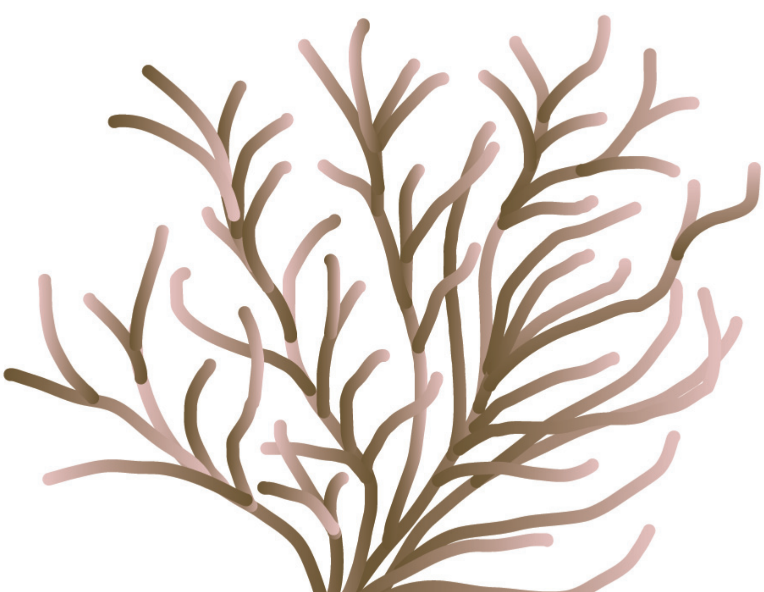
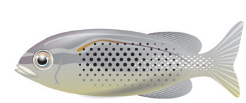




NOAA Resources

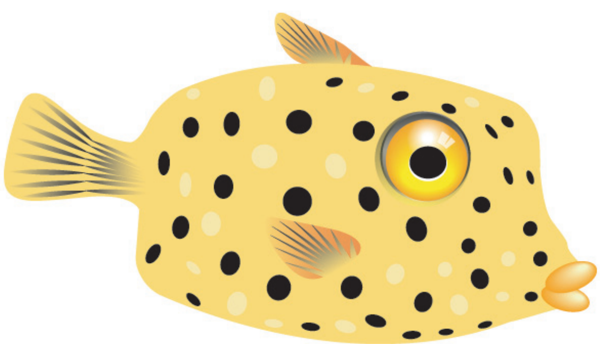
Below is a list of resources compiled by the Outreach Education Office of the National Oceanic and Atmospheric Administration. The science standards and the ocean literacy principles addressed in this unit were used as a guideline in selecting the following resources. To access the print resources listed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

- **Jet Stream, at http://www.srh.noaa.gov/srh/jetstream/matrix.htm**

- **"Build Your Own Weather Station" Activity in the Discover Your World with NOAA: An Activity Book, A NOAA 200th Anniversary celebration informal activity book can be found at http://celebrating200years.noaa.gov/edufun/book/welcome.html**
- **Access Pacific Hurricane Tracking Maps at http://www.nhc.noaa.gov**
- **Billy and Maria Weather Coloring Books, at http://www.nssl.noaa.gov/edu/bm/bm_main.html**
- **NOAA satellite data depicting currents, wave patterns and weather at www.coastalscience.noaa.gov/education/hibook.pdf**



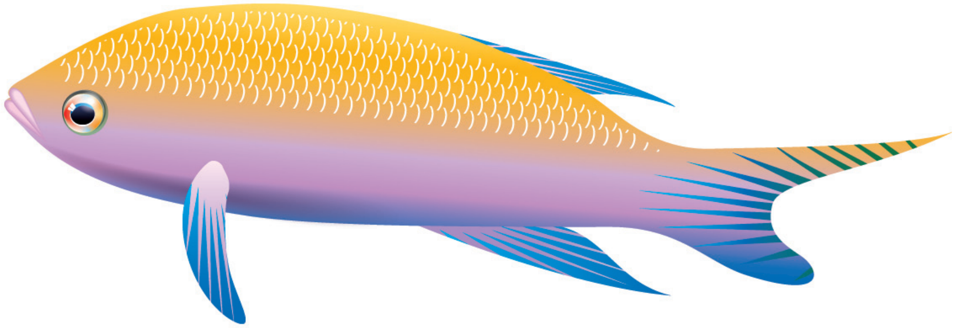
OCEAN LITERACY ESSENTIAL PRINCIPLES

2. Climate is regulated by complex interactions among components of the Earth's system.
   2e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.
6. The ocean and humans are inextricably interconnected.
   6c. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
   6f. Coastal regions are susceptible to natural hazards (tsunamis, hurricanes, cyclones, sea level change and storm surges).
7. The ocean is largely unexplored.
   7b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
   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: 6c
Lesson 2: 7d
Lesson 3: 7d
Lesson 4: 2e. 6f. 7b.7d. 7e.
Culminating lesson: 6c. 6f. 7b. 7d. 7e.

CLIMATE LITERACY ESSENTIAL PRINCIPLES

There is no appropriate alignment of Climate Literacy Essential Principles to the unit lessons.



NOAA Marine Science Career - Case Studies

Ian Morrison - Incident Meteorologist

National Weather Service Hawai‘i

When we hear the title meteorologist, we often think of our local weather station. Our friend, Ian Morrison has explored the field of meteorology and witnessed some pretty cool weather events. Ian shared with us his experience getting started in the field of meteorology. Ian also tells us about the craziest weather event he has ever witnessed!

Have you always been interested in weather patterns?
Weather has always been a big interest of mine. Since I can remember, growing up on the coast of Massachusetts, I’ve always looked forward to big weather events. Nothing compared to the ‘Perfect Storm’ that hit New England in October of 1991. The storm was so powerful that a book was written about it and then a movie was made. When the storm hit, I was safely away at school. Upon returning home, after the storm, there was only one lane on the road and it snaked from side to side around huge 20 foot piles of sand. State and National Guard workers had been working around the clock to get the road passable for emergency vehicles and residents. When I pulled up to my house, I was glad it was still there! Reports during the storm from ocean buoys and coastal observers showed the waves maxing out at 30 feet with storm tides along the coast of more than 13 feet. Add all of that to a storm surge of 5 feet and you get major coastal flooding. The waves came up over the dunes past the houses and then down onto the street. My house had a huge hole in the foundation where a loose tree rammed into it. The lanai that was in front of my grandparents house was picked up by the waves and floated 5 houses away. We had to have a tractor come and drag it back into place. Overall “The Perfect Storm” of 1991 was costly; the damage along the coast was estimated at $208 million and twelve lives were lost. This was the craziest weather event I have experienced, but I was fascinated by the power of the storm and I had many questions about the relationship between the weather and the ocean. Those questions and interests were what drew me into the field of meteorology.

How did you become a Meteorologist? I started out studying engineering when I first entered college at the University of Massachusetts. It was not until I applied to the University of Hawai‘i for graduate school that I majored in meteorology. After graduate school, I applied for several jobs all over the country with the National Weather Service and ended up in the remote mountain desert of Northern Nevada, in a small city named Elko. Yes, I know, I had not heard of it either. Although, Elko was not my first choice, it turned out that starting at a remote office actually allowed me to do more cool things than working in a well-known office. This allowed me to enter into the Incident Meteorologist (IMET) program, which usually takes years of working with NWS before you can even get a taste of IMET training. IMET’s are dispatched to large forest fires, hazmat spills, political conventions, etc. to do local on-site forecasts for the incident command team. I was a certified IMET by the time I left Elko two years later, and had been dispatched to large wild fires in California and Washington.
I transferred from Elko to the Monterey, California forecast office, and then nine months later, a forecast position at the Honolulu office opened up and I have been forecasting trade winds and mauka showers ever since.

Do you have any advice for students interested in weather? If you want to be a meteorologist, do well in math and science and start asking important questions about the weather where you live, such as, “Are the clouds the same in the morning as they are in the afternoon?” “Is there a time of day when it rains more” “Are the trade winds blowing today, or is the wind coming from a different direction?” Some of these questions, you can answer with your own observations and other answers can be found online, and in textbooks. The important thing is asking the questions and becoming more familiar with what is going on around you.

NOAA Marine Science Career Case Studies

Ray Tanabe - National Weather Service Forecast Office Honolulu Director of Operations

National Weather Service

Ray Tanabe is a Warning Coordination Meteorologist and works for the National Weather Service, under the National Oceanic and Atmospheric Administration (NOAA). Meteorology is the scientific study of the Earth's atmosphere, especially its patterns of weather and climate. Ray is going to share with us more about what a meteorologist does and how you can become a meteorologist too!

What sparked your interest in science and weather?

I grew up on the North Shore of Oahu and practically everything I did as a kid; surfing, fishing, hiking, camping, hunting, diving, etc. depended on the weather. Through my teenage years I really started to understand and appreciate how important weather is to almost everyone. Once, when I was driving from Waialua to Wahiawa I saw a funnel cloud form over the pineapple fields. It did not touch down and didn't do any damage, but it is still one of the coolest things I have ever seen.

My parents both encouraged me to study my passion, meteorology, and once I was in college, Dr. Thomas Schroeder encouraged me to continue through some epic college math class failures. There were many other students who had a difficult time in math and didn't receive their meteorology degree, simply because they gave up. Even though I'm no math wizard, with hard work and his guidance I proved to myself and others that I could get an 'A' in my final college math course. The science of meteorology relies heavily on complex mathematical equations and an excellent understanding of calculus, physics, chemistry and computer science. I attribute much of my success in this career to his help and support.

What does a meteorologist do?

Many people think a meteorologist is the person who explains the forecast on television. However, television meteorologists make up only a small percentage of career meteorologists. Meteorologists can find employment at universities, private companies, and the government where they are involved with research, teaching, consulting, and forecasting. Most meteorologists in the National Weather Service are 'operational forecasters' who produce weather forecasts 24 hours a day and are constantly on the lookout for severe weather such as tornadoes, flash flooding, high surf, high winds, hurricanes and extreme snowfall. One of the coolest things I've done in my career is save lives by forecasting severe weather. It was a great feeling when I accurately forecasted a flash flood and issued a warning ahead of time.

Which severe weather event should kids know more about and prepare for?

Hurricanes are arguably the most destructive weather systems on the planet and the threat is real and it is here today. While tornadoes pack severe winds and have produced a lot of damage and taken a lot of lives, they are relatively short lived and affect limited areas. Hurricanes have the ability to produce severe winds, flooding rains, and destructive storm surges which affect many miles of coastline and last several days to a week. The best way to be prepared is to familiarize yourself with the hurricane risks in your area, have an emergency kit, and have a family emergency plan.

Do you have any more advice?

A physics professor at UH once told our class there should be three things to consider when choosing a career. One, it should be something you like and enjoy. Two, it should be something you are innately good at. Three, it has to be something valued, meaning someone will pay you to do it. The vast majority of folks, he continued, settle for two out of the three. I feel I've been extremely fortunate, meteorology has provided me with all three.

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 "**K**now" about a topic. What they "**W**ant" to know about a topic. The last column students share what they have "**L**earned" 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 aide 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

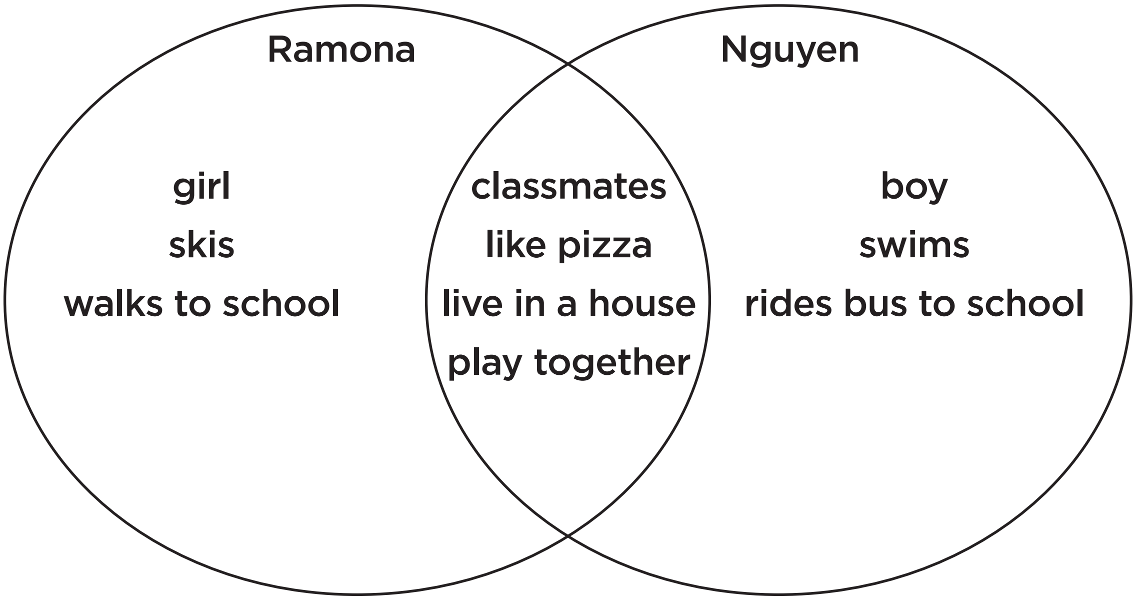
Round table can be used for brainstorming, reviewing, or practicing while also serving as a team builder. Students sit in teams of 3 or more, with one piece of paper and one pencil. The teacher asks a question which has multiple answers. Students take turns writing one answer on the paper, then passing 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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