Activity Title: Exploring changes in ocean chemistry

Subject (Focus/Topic): Oceanography: Chemical and Biological changes

Grade Level: 5th grade

Average Learning Time: Three 60-minute sessions

Lesson Summary (Overview/Purpose):

- Students will analyze and graph three marine water samples from South Florida, compare/contrast the results, draw inferences about the impact of freshwater on marine ecosystems, and improve the design of the experiment.

Overall Concept (Big Idea/Essential Question):

- The Earth's oceans are complex environments.

Specific Concepts (Key Concepts):

- Conduct an investigation related to chemical, physical and biological characteristics of the ocean environment (salinity, temperature, chlorophyll, CDOM).
- Graph and interpret data related to changing chemical characteristics of the ocean.
- Draw conclusions as to how ocean environments are affected by weather related factors.
- Infer as to how changes in basic chemical and physical characteristics (salinity, temperature, chlorophyll, CDOM) of the ocean affect the lives of marine organisms.
- Improve the experimental design of the experience.

Focus Questions (Specific Questions):

- What are some basic physical and chemical characteristics of the ocean? *(salinity, chlorophyll, temperature, CDOM)*
- How have ocean environments been affected weather related factors? *(Ex. flooding of the Mississippi River during spring/summer 2011*)
- How do changes in the Earth's oceans affect the ocean's ecosystems?
- How can scientists use graphical representations of data to better understand their results and draw conclusions?
- How can scientists improve upon the experimental design of this investigation?

Objectives/Learning Goals:

- Given a KWL chart, students will be able to identify four basic characteristics of the ocean (salinity, chlorophyll, temperature, CDOM) in the "Learned" section with 80% accuracy.

- Given three water samples, students will be able to compare/contrast the salinity, temperature, CDOM and amount of chlorophyll in each sample with 80% accuracy and students will be able to construct graphical representations of the data collected from the three water samples with 80% accuracy.
- Having created four graphs illustrating their results, students will be able to explain how the salinity, CDOM, chlorophyll and temperature of ocean environments are affected by the addition of a large freshwater plume with 80% accuracy.
- Having researched the delicate nature of ocean ecosystems, students will be able to infer how a freshwater plume affects the ocean's ecosystems with 80% accuracy.
- Having brainstormed potential pitfalls with the procedure, data collection and data analysis, students will improve the experimental design and draft a follow-up experiment to confirm their results and test their inference as to the effect of chemical changes on the marine ecosystems of South Florida.

Background Information:

- Oceans cover about 70 percent of the surface of Earth. The depth of the ocean varies. Ocean trenches are very deep, and the continental shelf is relatively shallow.
- Ocean water is a complex mixture of gases (air) and dissolved solids (salts, especially sodium chloride). Marine organisms are dependent on dissolved gases for survival. The salinity of ocean water varies in some places depending on rates of evaporation and amount of runoff from nearby land.
- Ocean currents, including the Gulf Stream, are caused by wind patterns and the differences in water densities (due to salinity and temperature differences). Ocean currents affect the mixing of ocean waters. This can influence plant and animal populations. Currents also affect navigation routes.
- Plankton are microscopic free-floating organisms that live in water. Plankton may be animal-like or plant-like. Animal-like plankton is called zooplankton. Plant-like plankton (phytoplankton) carries out most of the photosynthesis on Earth. Therefore, they provide much of Earth's oxygen. Phytoplankton forms the base of the ocean food web. Plankton flourishes in areas where nutrient-rich water upwells from the deep.
- Freshwater from the Mississippi River does not usually end up in the Florida Current in such high concentrations as it did during Summer 2011. The excessive rain and flooding along the Mississippi watershed in Spring 2011 greatly contributed to the amount of freshwater entering the Gulf of Mexico.
- The Mississippi River plume encountered around the Florida Keys in August 2011 was characterized by lower salinity, higher chlorophyll, a phytoplankton bloom, higher surface temperature, and higher CDOM (colored dissolved organic matter). The plume had an average thickness of 20-30 meters deep.

Excerpts from "Mississippi River Floodwaters Reach the Florida Keys during August 2011," AOML Keynotes (July/August 2011, Vol. 15, No. 4) (http://www.aoml.noaa.gov/keynotes/)

- As a result of the record flooding in the central U.S. during the spring of 2011, the Mississippi River stage and volume discharge to the Gulf of Mexico also reached record levels (as recorded by the U.S. Geological Survey). These values peaked in May 2011, resulting in a large pulse of fresh water, possibly laden with contaminants such as fertilizers, pesticides, and other materials due to its terrestrial origin, which entered and then spread across the northern Gulf.
- By July 2011, satellite remote sensing images of ocean color indicated that the Mississippi River discharge was beginning to spread southward as a narrow, coherent plume along the eastern edge of the Loop Current. A rough estimate, based on the southward progression of the plume as observed by ocean color imagery, suggested that the Mississippi River plume would reach south Florida's coastal waters from the Tortugas to the Keys by August 2011.
- Scientists from the Ocean Chemistry and Physical Oceanography divisions recently completed an extended version of their regular interdisciplinary SFP sampling program on August 2-7, 2011 aboard the R/V *F.G. Walton Smith*, and were able to document the delivery of Mississippi River water to the Florida Keys using the onboard flow-through C6 seawater system. The instrument continuously recorded surface temperature, salinity, chlorophyll, chromophoric dissolved organic matter (CDOM), turbidity, crude oil, and other parameters.
- A satellite-derived, three-day composite image of ocean color from NASA's MODIS Aqua satellite, recorded on August 5-7, 2011, shows a plume of relatively high chlorophyll from the Mississippi River extending from the northern Gulf of Mexico to the Tortugas Gyre, which then spreads to the northeast towards Miami along the onshore front of the Florida Current.
- Surface water properties from the ship-board flow-through C6 system indicated that although there was a phytoplankton bloom located along the southwest Florida shelf that dominated most of the signals, there was a lower magnitude but still very distinct signal from the Mississippi River plume most evident in the Tortugas Gyre sections.
- Surface properties measured along the portion of the cruise track between the Dry Tortugas and the southernmost point below Key West show that the water was relatively lower in salinity and higher in chlorophyll within the river plume as opposed to the surrounding waters of the Gulf of Mexico and Florida Current. The river water was also associated with relatively higher surface temperature, CDOM, turbidity, and crude oil (not shown). CTD profiles revealed that the Mississippi River plume thickness reached a depth of approximately 20-30 meters in the vertical.
- The ecological effects on south Florida's ecosystems caused by terrestrial origin river discharges are not yet fully understood. When the cruise data, including the extra biogeochemical sampling, are fully analyzed it may provide further insight into the downstream consequences of the 2011 Mississippi River flood.
- The Mississippi River flood plume during 2011 provided a graphic demonstration of a direct transport mechanism capable of delivering materials from the northern Gulf to the Florida Keys, often quite rapidly with a time scale of days to weeks. In the summer of 2010, following the Deepwater Horizon oil spill in the northern Gulf, scientists from AOML documented that such a direct pathway was not present at the critical time and found no sign of oil south of about 28 °N. Had the oil spill occurred during 2011 rather than 2010, its consequences for the sensitive coral reefs, sea grass

beds, mangrove shore- lines, and sandy beaches of south Florida could have been a dramatically different story.

Excerpts from Caitlin Fine's Teacher at Sea Blog, "Chemistry is All Around Us!," August 4, 2011.

http://teacheratsea.wordpress.com/2011/08/05/caitlin-fine-chemistry-is-all-around-us-august-4-2011/

As I said yesterday, the oceanographic work on the boat basically falls into three categories: physical, chemical and biological. Today I will talk a bit more about the chemistry component of the work on the R/V *Walton Smith*. The information that the scientists are gathering from the ocean water is related to everything that we learn in science at Key – water, weather, ecosystems, habitats, the age of the water on Earth, erosion, pollution, etc.

First of all, we are using a CTD (a special oceanographic instrument) to measure salinity, temperature, light, chlorophyll, and depth of the water. The instrument on this boat is very large (it weights about 1,000 lbs!) so we use a hydraulic system to raise it, place it in the water, and lower it down into the water.

Lindsey takes a CO2 sample from the CTD

The CTD is surrounded by special niskin bottles that we can close at different depths in the water in order to get a pure sample of water from different specific depths. Nelson usually closes several bottles at the bottom of the ocean and at the surface and sometimes he closes others in the middle of the ocean if he is interested in getting specific information. For each layer, he closes at least 2 bottles in case one of them does not work properly. The Capitan lowers the CTD from a control booth on 01deck (the top deck of the boat), and two people wearing a hard hat and a life vest have to help guide the CTD into and out of the water. Safety first!

Once the CTD is back on the boat, the chemistry team (on the day shift, Lindsey and I are the chemistry team!) fills plastic bottles with water from each depth and takes them to the wet lab for processing. Throughout the entire process, it is very important to keep good records of the longitude and latitude, station #, depth of each sample, time, etc, and most importantly, which sample corresponds to which depth and station.

We are taking samples for 6 different types of analyses on this cruise: nutrient analysis, chlorophyll analysis, carbon analysis, microbiology analysis, water mass tracers analysis and CDOM analysis.

The ***nutrient analysis*** is done to understand how much of each nutrient is in the water. This tells us about the availability of nutrients for phytoplankton. Phytoplankton need water, CO_2, light and nutrients in order to live. The more nutrients there are in the water, the more phytoplankton can live in the water. This is important, because as I wrote yesterday – phytoplankton are the base of the food chain – they turn the sun's energy into food.

Sampling dissolved inorganic carbon

That said, too many nutrients can cause a sudden rise in phytoplankton. If this occurs, two things can happen: one is called a harmful algal bloom. Too much phytoplankton (algae) can release toxins into the water, harming fish and shellfish, and sometimes humans who are swimming when this occurs. Another consequence is that this large amount of plankton die and fall to the seafloor where bacteria decompose the dead phytoplankton. Bacteria need oxygen to survive so they use up all of the available oxygen in the water. Lack of oxygen causes the fish and other animals to either die or move to a different area. The zone then becomes a "dead zone" that cannot support life. There is a very large dead zone at the mouth of the Mississippi River. So we want to find a good balance of nutrients – not too many and not too few.

The ***chlorophyll analysis*** serves a similar purpose. In the wet lab, we filter the phytoplankton onto a filter.

I am running a chlorophyll analysis of one of the water samples.

Each phytoplankton has chloroplasts that contain chlorophyll. Do you remember from 4th grade science that plants use chlorophyll in order to undergo photosynthesis to make their own food? If scientists know the amount of chlorophyll in the ocean, they can estimate the amount of phytoplankton in the ocean.

Carbon can be found in the form of carbon dioxide (CO_2) or in the cells of organisms. Do you remember from 2nd and 4th grade science that plants use CO_2 in order to grow? Phytoplankton also need CO_2 in order to grow. The ***carbon dioxide analysis*** is useful because it tells us the amount of CO_2 in the ocean so we can understand if there is enough CO_2 to support phytoplankton, algae and other plant life. The carbon analysis can tell us about the carbon cycle – the circulation of CO_2 between the ocean and the air and this has an impact on climate change.

The ***microbiology analysis*** looks for DNA (the building-blocks of all living organisms – kind of like a recipe or a blueprint). All living things are created with different patterns or codes of DNA. This analysis tells us whose DNA is present in the ocean water – which specific types of fish, bacteria, zooplankton, etc.

The ***water mass tracers analysis*** (on this boat we are testing N15 – an isotope of Nitrogen, and also Tritium – a radioactive isotope of Hydrogen) helps scientists understand where the water here came from. These analyses will help us verify if the Mississippi River water is running through the Florida Coast right now. From a global viewpoint, this type of test is important because it helps us understand about the circulation of ocean water around the world. If the ocean water drastically changes its current "conveyor belt" circulation patterns, there could be real impact on the global climate. (Remember from 2nd and 3rd grade that the water cycle and oceans control the climate of Earth.) For example, Europe could become a lot colder and parts of the United States could become much hotter.

The last type of analysis we prepared for was the ***CDOM (colored dissolved organic matter) analysis***. This is important because like the water mass tracers, it tells us where this water came from. For example, did the water come from the Caribbean Sea, or did it come from freshwater rivers?

I am coming to understand that the main mission of this NOAA bimonthly survey cruise on the R/V *Walton Smith* is to monitor the waters of the Florida Coast and Florida Bay for changes in water chemistry. The

Florida Bay has been receiving less fresh water runoff from the Everglades because many new housing developments have been built and fresh water is being sent along pipes to peoples' houses. Because of this, the salinity of the Bay is getting higher and sea grass, fish, and other organisms are dying or leaving because they cannot live in such salty water. The Bay is very important for the marine ecosystem here because it provides a safe place for small fish and sea turtles to have babies and grow-up before heading out to the open ocean.

Common Misconceptions/Preconceptions:

- As soon as freshwater enters the ocean, it immediately mixes with the saltwater and disappears.
- Freshwater and saltwater are basically the same chemically.
- The ocean is so large that it cannot be affected chemically by freshwater runoff from rivers.
- Marine organisms cannot be affected by large amounts of freshwater.
- Fresh river water is clean and pure – it does not contain contaminants, like fertilizers and pesticides, which can harm living organisms.
- There is only one correct way to conduct an experiment. Scientists do not change/improve upon their experimental designs.

Materials:

- Enough of the three water samples for students to work in groups of 4-5 students
- 4-5 hydrometers (to measure salinity)
- Salt
- Glitter (represents chlorophyll)
- Green and blue food coloring (for CDOM…green represents water from the Mississippi River, blue represents water from South Florida)
- 4-5 thermometers
- Water (three different temperatures)
- 12-15 beakers or bottles for water samples
- Graphic organizer with explanation of indicators
- Data sheet to record data from water samples
- Large paper to make graphical representations (4 pages/group)
- Paper to take notes and write summaries/conclusions/inferences/experimental design improvements
- Pencils
- Markers
- KWL chart to gather background knowledge
- Computers with access to Internet (at least 1 per group)

Technical Requirements:

- Internet to show satellite images of the Mississippi River plume in the Florida Keys
- Elmo or overhead projector to project satellite images of the plume and photos from Caitlin Fine's Teacher at Sea blog
- Access to computers and Internet for student research (at least 1 computer per group)

Teacher Preparation:

- Print the KWL, graphic organizer, and data sheet (one for each student)
- Create an outline to assist students with taking notes from their Internet research
- The teacher needs to prepare the three water samples in advance. All of the materials, minus the water, can be mixed together in advance. The warmer Mississippi River water can be heated up in microwave and then added to the other Mississippi River water sample ingredients right before the lesson. Make sure to mix it until all of the salt dissolves.
  - "Florida Current Water June 2011" = high salinity (36 grams/liter), low chlorophyll (less glitter), low surface temperature ("cold" water – 75F), CDOM (blue food coloring)
  - "Florida Current Water July 2011" = low salinity (25 grams/liter), higher chlorophyll (medium glitter), higher surface temperature ("warm" water – 80F), CDOM (green/blue food coloring).
  - "Florida Current Water August 2011" = lowest salinity (15 grams/liter), higher chlorophyll (more glitter), higher surface temperature ("warmest" – 85F water), CDOM (green food coloring).

Keywords: salinity, chlorophyll, temperature, CDOM, chemical oceanography, ecosystem, plume

Pre-assessment Strategy/Anticipatory Set (Optional):

- Distribute the KWL sheet to students. Direct them to fill out the "Know" and "Want to know" sections in response to the following prompt:
  - How does the weather affect the ocean and how do these changes affect the plants and animals that live in the ocean?

- As students complete the KWL, have them share their information with a partner. Finally, have several students share their knowledge and questions with the entire class. Record this information on a class KWL chart.

Lesson Procedure:

Building Background Knowledge

- Show the video from the CBSNews link (below) to demonstrate to students the extent of the Mississippi River flooding during May-June 2011. http://www.cbsnews.com/stories/2011/05/07/national/main20060801.shtml

- Distribute the NOAA article about the flooding Mississippi River and predictions about flood damage for the marine ecosystems in the Gulf of Mexico. Highlight important parts with students since much of the text might be difficult for them to understand. (http://www.noaanews.noaa.gov/stories2011/20110614_deadzone.html)

- Show students the NOAA satellite image of the Gulf of Mexico and South Florida from Keynotes July/August 2011. Ask students what they observe. Discuss their observations. http://www.aoml.noaa.gov/keynotes/

    - Or go to http://www.aoml.noaa.gov/phod/dhos/index.php - select "Mississippi River Water Discharge Monitoring" and select date or month (July/August) to view images of sediments (Rrs667) or organic/inorganic particles (K490).

Introducing Water Sampling

- Explain to students that today they will be in charge of analyzing three water samples taken from the same spot on different dates to determine if the Mississippi River plume reached South Florida:
    - Florida Current water - June 2011
        - This is the water found along the Florida Keys in the month before the Mississippi River plume reached South Florida.
    - Florida Current water – July 2011
        - This is the water found along the Florida Keys in the month that the Mississippi River plume reached South Florida.
    - Florida Current water – August 2011
        - This is the water found along the Florida Keys in the month after the Mississippi River plume began to reach South Florida.
- Explain to students that they will look at 4 indicators: salinity, temperature, chlorophyll and CDOM. Pass-out the graphic organizer with indicator names, explanations of each indicator, and "typical" results for South Florida marine water and Mississippi River water. Give students 5 minutes to read through the information in their groups. Answer any questions students have. Demonstrate how to use the hydrometer and thermometer.

Investigating Indicators

- Pass-out the water samples and the data-recording sheet. Give students 10 minutes to analyze the three water samples and record their data. Move around the table and help students as needed throughout this part.
- Ask one "reporter" for each group to share the group's results. Verify that all groups have more or less the same results. Retest if necessary. ***[YOU MAY STOP "Day 1" AT THIS POINT.]***
- Challenge groups to make four graphical representations of their results – one for each indicator. Give groups about 15-20 minutes to work on their graphs. Post the graphical representations around the room and have a second "reporter" explain the group's graphical representations. Classmates should offer suggestions/constructive feedback to those groups that need extra help.
- Each group should write a summary of their results and their conclusions. They should include answers to the following questions:
    - Were the three water samples different?
    - What specifically was different about the three samples?

    - Does it appear as though the Mississippi River plume affected the chemistry of the South Florida ocean water? Why or why not?

Inferring/Predicting from Data and Designing Future Research

- Explain that one important thing scientists do is to draw inferences/predictions from their observations. In this case, you want them to draw inferences about how they believe the Mississippi River plume will/will not affect the South Florida marine ecosystems.
- Groups will have about 30 minutes to use the Internet to research the impact of changes in temperature, salinity, and presence of chlorophyll (nutrients) on marine ecosystems in general. Each group should record the results of their research in bullet points. ***[YOU MAY STOP "Day 2" AT THIS POINT.]***
- Each group should use their notes from the Internet research to compose at least one paragraph outlining their predictions about the impact of the Mississippi River plume in the South Florida marine ecosystems.

Improving the Experimental Design

- Review the experimental procedure, results and conclusions.
- Explain that one thing scientists do is to think about pitfalls in their procedure, data collection and analysis methods. Scientists also have to decide if further research is needed to answer their question(s).
    - Encourage students to work with their groups to brainstorm with a list of at least 5 things that could be improved the next time they conduct this experiment so that the results might be more accurate.
    - Focus Questions:
        - Should they take more water samples?
        - Should they take samples at different depths?
        - Should they return a week or a month later to re-test?
        - Should they improve their testing methods? (How and why?)
        - Should they test for more/different indicators?
    - How could students determine if, in fact, the Mississippi River plume affects the marine ecosystems of South Florida?
        - What materials will they need to answer this question?
        - What type of data would they be collecting? (water samples, fish and plant samples, etc.)

Assessment and Evaluation:

- Complete KWL
- Complete data sheet
- Graphical representations (4)

- Summary of results and conclusions
- Document with research about indicators and inferences about how the Mississippi River plume will affect South Florida's marine ecosystems.
- List of ways to improve the experimental design of the investigation
- Outline and guiding questions for future experiment(s)

Standards:
National Science Education Standard(s) Addressed:
- NSES A: Unifying concepts and processes in science
  - Subcategories: 1, 2, 3, 4
- NSES B: Science as inquiry
  - Subcategories: 1, 2
- NSES D: Life science
  - Subcategories: 1, 4, 5
- NSES F: Science and technology
  - Subcategories: 1, 2
- NSES G: Science in personal and social perspectives
  - Subcategories: 2, 3, 4, 5
- NSES H: History and nature of science
  - Subcategories: 1, 2

Ocean Literacy Principles Addressed:
- Ocean literacy principal #1: The Earth has one big ocean with many features.
  - Fundamental concepts: a, c, e, g
- Ocean literacy principal #4: The ocean makes the Earth habitable.
  - Fundamental concepts: a
- Ocean literacy principal #5: The ocean supports a great diversity of life and ecosystems.
  - Fundamental concepts: a, b, c, f
- Ocean literacy principal #6: The ocean and humans are inextricably interconnected.
  - Fundamental concepts: e, f, g
- Ocean literacy principal #7: The ocean is largely unexplored.
  - Fundamental concepts: a, b, c, d, e, f

State Science Standard(s) Addressed:
Virginia Standards of Learning
Strand: Interrelationships in Earth/Space Systems
SOL: 5.6
The student will investigate and understand characteristics of the ocean environment. Key concepts include
a) geological characteristics;
b) physical characteristics; and
c) ecological characteristics.

Other National or State Standards Addressed (Optional)

Additional Resources: List any books, articles, Web sites, videos, etc. that may enhance this lesson for students, teachers, parents/guardians or others.

- http://news.nationalgeographic.com/news/2011/05/pictures/110510-mississippi-river-memphis-tennessee-flood-record-crests-nation/#/mississippi-river-historic-floods-2011_35440_600x450.jpg
- http://teacheratsea.wordpress.com/2011/08/05/caitlin-fine-chemistry-is-all-around-us-august-4-2011/
- http://www.aoml.noaa.gov/phod/sfp/index.php
- http://www.aoml.noaa.gov/phod/sfp/data/ship_obs.php
- http://www.noaanews.noaa.gov/stories2011/20110706_floodthreat.html
- http://earthobservatory.nasa.gov/IOTD/view.php?id=51167
- http://www.nola.com/environment/index.ssf/2011/08/dead_zone_larger_than_average.html
- http://www.epa.gov/bioiweb1/aquatic/marine.html
- http://www.marinebio.net/marinescience/02ocean/swcomposition.htm
- http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CBoQFjAA&url=http%3A%2F%2Fwww.ysi.com%2Fmedia%2Fpdfs%2FT606-The-Basics-of-Chlorophyll-Measurement.pdf&ei=6KWwTqF7gffSAZ7x_dQB&usg=AFQjCNHdE5y_x90fBmdEnwiUoPtr8CG24w&sig2=OYcCgbQyJABw-8IIz6lSKg

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Data Sheet for Water Sampling

Indicator	**Sample #1: June 2011**	**Sample #2: July 2011**	**Sample #3: August 2011**
Salinity (grams/liter)			
Temperature (C)			
Chlorophyll (descriptive: amount of glitter)			
CDOM (descriptive: water color)			

Four Indicators for Water Sampling

Indicator	Definition	Important because…	"Typical" Mississippi River profile	"Typical" South Florida profile
Salinity	The amount of salt dissolved in sea water	Marine organisms have adapted to live in water with specific amounts of salinity. If the salinity changes quickly, the organism can not adapt or move and may die.	5 grams/liter	36 grams/liter
Temperature	The amount of heat in the water	The temperature of seawater depends on the amount of sunlight that's received in the area and the depth of the ocean. Seawater temperature affects marine organisms by changing the reaction rates inside their cells. Organisms may die if they are forced to live outside of their temperature tolerance range.	35C/95F	30C/87F
Chlorophyll	A green pigment, present in all green plants and in cyanobacteria, responsible for the absorption of light to provide energy for photosynthesis.	Surface waters that have high chlorophyll are usually high in nutrients. These nutrients cause algae to grow or bloom. When algae populations bloom, then crash and die in response to changing environmental conditions, they deplete dissolved oxygen levels - a primary cause of most fish kills. High levels of nutrients (nitrogen and phosphorus) can be indicators of pollution from man-made sources, such as fertilizer runoff.	0.18 mg/m3	0.7 mg/m3
CDOM	Stands for "Colored Dissolved Organic Matter"	CDOM can impact marine organisms because it diminishes light. It can limit photosynthesis and prevent the growth of phytoplankton (which forms the basis of oceanic food chains and are the major source of oxygen on Earth). Generally CDOM levels are higher in fresh water and lower in open ocean.	High (green)	Low (blue)

KWL chart

"How does the weather affect the ocean and how do these changes affect the plants and animals that live in the ocean?"

Know	Want to Know	Learned