1.1 Water Density Stations: Learning about TSI Phases and learning cycles through water density (WDS)

Goals

In terms of learning cycle investigation, students will…

1. Explore the advantages and limitations of different teaching approaches
2. Explore the idea that everyone learns differently
3. See the importance of incorporating a variety of teaching approaches and trying to achieve a balance among them
4. Understand that effective teaching employs a sequence of different teaching approaches to achieve greater learning.
5. Reflect on their own learning styles and better understand what helps them to learn personally
6. Learn the Teaching Science as Inquiry (TSI) phases of inquiry science learning.

In terms of content, students will…

7. Explore the effect of temperature on relative density
8. Explore the effect of salinity on relative density
9. Explore the effect of salinity and temperature on the speed of ice melting
10. Use relative density to distinguish salt verses fresh water
11. Apply density concepts to water circulation

Ocean Literacy Principles

<u>Principle 1: *The earth has one big ocean with many features*</u>

Ocean Literacy Fundamental Concept: Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of the earth's rotation (Coriolis effect), the sun, and water density differences. The shape of the ocean basins and adjacent landmasses influence the path of circulation. (OLP 1c)

Ocean Literacy Fundamental Concept: Most of Earth's water (97 percent) is in the ocean. Seawater has unique properties: it is saline, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. The salt in seawater comes from eroding land, volcanic emissions, reactions at the seafloor, and atmospheric deposition. (OLP 1f)

Standards Addressed

T-WDS Table 1.1. HCPS III Benchmarks

Science		
Standard 1	Scientific Investigation	Discover, invent, and investigate using the skills necessary to engage in the scientific process
1.1	Design and safely conduct a scientific investigation to answer a question or test a hypothesis	
1.2	Communicate the significant components of the experimental design & results of a scientific investigation	
MS.1.1	Describe how a testable hypothesis may need to be revised to guide a scientific investigation	
MS.1.2	Design and safely implement an experiment, including the appropriate use of tools and techniques to organize analyze, and validate data	
MS.1.3	Defend and support conclusions, explanations, and arguments based on logic, scientific knowledge, and evidence from data	
MS.1.4	Determine the connection(s) among hypotheses, scientific evidence and conclusions	

Social Studies		
Standard 1	Associative Learning	Examine the results of social cognitive theory on knowledge acquisition and learning

Career and Technical Education		
Standard 2	Career planning	Show documentation of learning and growth
Standard 2	Education and job training	Explain that current learning relates to life outside the classroom

Background and Introduction

Summary

During this activity, students will rotate through a series of learning stations. Each station uses a different teaching approach to present the same density topic. As students visit each station, they will be challenged to analyze their reaction to the different teaching approaches. After the series of activities, the instructor will lead a discussion of participants' experiences and thoughts, helping the class to reflect on and compare the strengths of various kinds of learning approaches. The instructor draws out the fact that different cultures and different learners have different abilities and preferences for teaching approaches, highlighting how important it is for an educator to use a variety of approaches and how important it is for learners to actively engage in the learning process. The instructor then introduces the idea of learning cycles and the phases of inquiry used in the Teaching Science as Inquiry (TSI) model of science learning and teaching.

Cautions about using this activity with students

This activity was developed by education researchers at the University of California, Berkeley's Lawrence Hall of Science (LHS) and is copyrighted 2005 by the Regents of the University of California. This activity was originally designed as a learning activity for adults (teachers, informal educators, graduate students, and professional scientists) as part of the UC Berkeley LHS courses in Communicating Ocean Science (COS) developed in partnership with their Center for Ocean Science Education Excellence – California (COSEE-CA). This activity was not designed for students!

Nevertheless, because this activity is both fun and effective at engaging people's interest in learning styles and ocean science, teachers who experience the activity often want to share it with their students. This teacher guide is designed to help facilitate use of the COS activity with students. However, teachers need to recognize the limitations of the activity. For example, sharing this activity with students may have the side effect of confusing students on the topic of density, resulting in the need to directly, and authoritatively, cover some of the concepts on density and ocean circulation that students are not able to figure out on their own during the activity itself.

Learning style content covered

This activity is designed to help students explore how they have been taught to learn, how they learn best, and how other people learn best. Students should learn about various types of instruction and learning styles. Students should also relate these learning styles to the ways they learn at home and in other cultural settings. After the lesson, students should be able to recognize various teaching approaches and how they, as learners, can adapt their strategies to make the most of the teaching approach offered. Students should also begin to build strategies to seek learning environments that benefit their preferred learning styles. The overall goal is to build students' learning awareness. Helping students to connect their views of the traditional, cultural, and outside world with their science world can also improve the way they approach science and the study of nature, helping them to maintain cultural foundations while at the same time building conceptual knowledge.

Key learning style points to remember are:

- Learning cycles are instructional models that partition the learning process into phases that use different teaching approaches. The idea of learning cycles grew out of science education research in the 1960s as scientists and educators wrestled with more effective ways to help students acquire, retain, and apply important concepts. The idea of learning cycles has been refined in recent years by findings in neuroscience and cognitive psychology. The learning cycle is instrumental in presenting educational experiences that are consistent with what is known about how people learn.
- The TSI phases allow students to conceptually link the scientific process of inquiry with their learning process in a multidirectional model that mimics the action of professional scientists.
- The TSI phases, and other learning cycles, are instructional models that are learner-centered, meaning they take into account the learner's prior understandings and need for first-hand experiences. They enable students to integrate and apply new concepts and information.
- Learning cycles are not rigid, nor is any type of learning cycle the only way to learn, nor the only way to practice science. People and their learning processes are complex, and depending on the person and the content being learned there is no automatic order or sequence in which the phases must take place.
- The TSI phases, and other learning cycles, can be powerful in stimulating thinking about how people learn, in designing lessons, and in taking ownership over ones own learning.

Density content covered

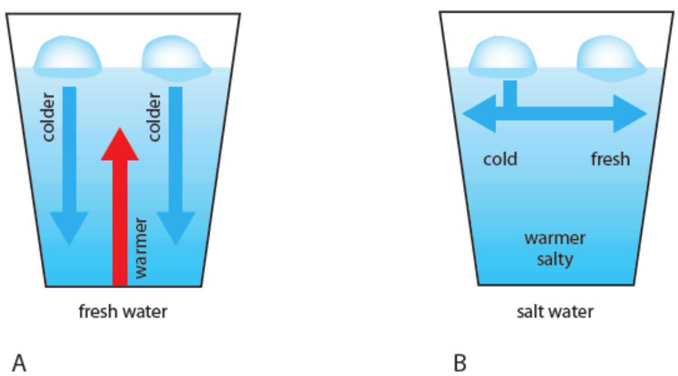
This activity focuses on relative density between cold, warm, fresh, and salt water. The relative density differences are applied to the practical scenarios of 1) determining fresh verses salt water, 2) determining the relative melting speed of ice in fresh verses salt water, and 3) predicting the effect of relative density on ocean circulation.

Key content points to remember are:

- Ice melts faster in fresh water than in salt water.
- In the ocean, movement of large masses of water is partially regulated by the density of these water masses. Density is defined as the amount of matter contained in a given volume.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

- Small density differences between water masses, for example beween water masses that are only a few degrees different in temperature or have just slightly different salinities, play a major role in the formation of water layers in the ocean and in ocean circulation.
- The activity in this topic explores the *relative density* between fresh water, hypersaline water (hypersaline water is defined here as water that has a higher salinity than the ocean), cold (ice) water, and warm (room temperature) water.
- Cold water is more dense than warm water because the water molecules are closer together
- Salt water is more dense than fresh water because it has more “stuff” (salt) packed into the same volume of water.
- Hypersaline water is more dense than cold water because the salt ions can fit into the spaces between the water molecules more tightly than water molecules can fit together, even when water is very cold.
- Students use these relative densities to investigate why ice melts slower in salt water than fresh water (because it creates a fresh water lens, see T-WDS Fig. 1.1) and the role of density in driving ocean circulation.



T-WDS Fig. 1.1 Relative melting of ice in fresh water (A) and warm water (B). The denser, cold water from the melting ice sinks to the bottom of the cup in fresh water (A). However, since the cold water from the melting ice is less dense than the salt water, it floats on the top of the salt water (B), thus the cold, fresh water from the melting ice helps keep the ice cold. Therefore, the ice melts more slowly in salt water.

Common Misconceptions

T-WDS Table 1.2. Learning and practices of science misconceptions

Misconception	Explanation
The scientific process is linear and uni-directional.	Scientists report their finding linearly using the formal scientific method, but the actual process of science is fluid and multidirectional.
Science is a static body of knowledge that does not change.	Science is only able to provide the best possible explanation based on available evidence. As evidence grows and methods of analysis improve, our understandings grow and change.
Only (professional) scientists can do science.	The scientific process is important in all walks of life, and all people are capable of thinking and acting scientifically.
If your hypothesis is not supported, your investigation has failed.	Lack of support for a hypothesis may mean that your study needs to gather new or more information, or it may mean that you need a new method of investigation. Lack of support might also mean your hypothesis is incorrect or needs to be modified. Any of these outcomes still provides useful information and helps you to focus your efforts in better understanding the system you are studying.
Hypotheses cannot change.	Hypotheses change as a result of evidence and analysis. The process of modifying hypotheses is how science grows and learns.

<u>Additional Misconceptions</u>

Density
Aquatic Misconceptions

- Substances (e.g. salt/sugar) dissolved in water do not affect the overall weight.
- Density does not cause currents; only waves cause currents.
- Water is water. Water in the ocean has the same properties everywhere.
- Water in the ocean is the same from top to bottom – it doesn't form layers.
- Confusion between density, buoyancy, and gravity.

T-WDS Table 1.3. Suggested activity time, if adhering closely to activity as written with no major modifications, assuming class periods of 40 minutes

	Minutes	**Task**
Outside of Class	30	Prep supplies
	30	Clean up
	60	Read and respond to student reflections on how they learn
Day 1	20	Introduction to learning styles and cultural ways of knowing and learning.
	20	Introduction to activity and activity stations. This may also be done on the same day as the activity stations if you have enough class time.
	Homework (optional)	Assign students writing reflection on how they think they learn best and what types of learning they are culturally familiar with.
Day 2	10 (optional)	Density discussion to prime students on density content.
	30-40	Activity stations. There are 4 stations (A-D) + an optional 5th station. Students should have at least 10 minutes at each station. One of the stations can be assigned as homework.
	Homework	• Students read station C handout “Mystery Water – What Happened and Why”. • You can assign station D (question and answer station) and station E (optional, video and answer) as homework (unless you have long enough class periods that all stations can be done in class)
Day 3	20	Debrief stations
	20	Introduce learning cycles and TSI phases of inquiry
	Homework	Assign student writing reflection on which station they preferred, how the order of the stations affected their learning, and how they can use the results of this activity to help them learn in other situations.

T-WDS Table 1.4a. Class materials. This table has all of the materials needed for this activity and can be used when purchasing and organizing supplies. The subsequent tables (Tables 1.5-1.9) show materials by station for classroom set-up. If you adhere closely to activity as written with no major modification, assuming a class of 32 students divided into groups of four, there will be 8 groups, which is 2x each of the 4 stations.

Materials	**Quantity**	**Per**	**Class Total** (assuming 2 of each station)	**Notes on Material Number or Material Modification**
Powerpoint guide to stations (optional)	1	Class	1	Powerpoint will help to guide you through the stations and TSI phases.
Large poster paper	4-5	Class	4-5	Use poster paper for recording student ideas about each station. You will need 4-5 pieces of paper, depending on if you do station E.
Laminated copies of each station sign with directions	1	Station A, B, C, D + optional E	8 or 10	With a class of 32 split into 8 groups, you will have two of each of the four stations (i.e. 2 each of station A, B, C, and D). You may also have a station E (optional). Sheet protectors work well as "lamination".
Station B worksheet	4	Station B	8	"Structured Activity Station Instructions"
Station C handout (**given after stations**)	1	Student	32	"Mystery Water – What Happened and Why". **Do not hand out until after station rotations.**
Station D worksheet (may be homework)	1	Student	32	"Read and Answer" sheet. Note that two examples of this worksheet are provided to choose from. Note also that if you do not have time in class, you may do this as a homework station.
Station E (optional) worksheet	1	Student	32	"Questions on the Video" sheet. One example video and worksheet are provided. Note that this station is optional and may also be done as homework.
Kosher salt	11 tbs	Gallon of water	33tbs	Add 11tbs of kosher salt to 1 gallon of fresh water to make salt water. Allow the solution to sit until water is no longer turbid. Use this solution to fill pitchers for stations A-C of the activity. This makes a solution of about 40 parts per thousand (ppt). This salinity ensures that food coloring density isn't a factor in the saltwater part of the experiment and makes the visual impact more dramatic.)
Long stir stick or spoon	1	Class	1	You will need a long spoon, a stir stick, or a ruler to stir the kosher salt into the water
Small stir stick or spoon	1	Station A	2	Students will need a small spoon (e.g. tablespoon) or stir stick to stir salt into cups at station A.

T-**WDS Table 1.4b.** Class materials continued.

Materials	Quantity	Per	Class Total (assuming 2 of each station)	Notes on Material Number or Material Modification
Pitchers of salt water	1	Station A, B, & C	6	About 40 ppt. See directions above under kosher salt material.
Pitchers of fresh water	1	Station A, B, & C	6	Tap water is fine.
Large sheet of paper	1	Station A, B, & C	6	A piece of flip chart paper works well.
Food coloring	1	Station A, B, & C	6	Any dark color (e.g. blue, green, or red)
Small ice container	1	Station A, B, & C	6	Small plastic bowl or beaker to hold ice cubes
Ice cubes & cooler or freezer	2-4	Station A, B, & C	64-112	Ice cubes need to be approximately the same size and relatively large. Crushed ice will not work. A cooler or freezer for storing ice cubes is also needed.
Sponge	1	Station A, B, & C	6	For cleanup.
Small waste container or sink	1	Station A, B, & C	6	To dispose of used water. A sink may also be used.
Small container of kosher salt	2	Station A	2	For students to use at stations.
Towels	1	Station A, B, & C	6	A rag or hand towel for drying hands and cleaning up station
Thermometer	2	Station A & C	8	For students to use in measuring water temperature.
Miscellaneous sinking and floating objects	15	Station A & C	60	Small vials, BB pebbles, corks, push pins, packing peanuts, marbles, blocks, crayons, chalk, balloons, and paperclips work well.
Computer(s) or other technology to show video	1	Station E	1-2	You may choose to do station E as a class and use only one TV, projector, or computer to show the video. You may also do station E as a single station or as two stations, depending on your equipment.
Speakers or earphones	1	Station E	1-2	You may choose to do station E as a class and use only one speaker. You may also do station E as a single station or as two stations, depending on your equipment.

T-WDS Table 1.5. Station A – Open-ended Exploration Materials. Assuming a class of 32 students divided into groups of four (8 groups), you will have two station As.

Materials	Quantity	Per	Total for 2 Station As	Notes on Material Number or Material Modification
Laminated copy of Station A Activity sheet	1	Station A	2	
Identical clear containers	2	Station A	4	Plastic cups or beakers; approximately 12 ounce. Cups or beakers with smooth sides (no ridges) work best.
Large sheet of paper	1	Station A	2	A piece of flip chart paper works well.
Food coloring	1	Station A	2	Any dark color (e.g. blue, green, or red)
Small ice container	1	Station A	2	Small plastic bowl or beaker to hold ice cubes
Ice cubes	2-4	Group to rotate through Station A	16-32	Each rotation through the station will use about 2-4 ice cubes.
Sponge	1	Station A	2	For cleanup.
Towel	1	Station A	2	A rag or hand towel for drying hands and cleaning up station
Small waste container or sink	1	Station A	2	To dispose of used water. A sink may also be used.
Small container of kosher salt	2	Station A	2	For students to use.
Small stir stick or spoon	1	Station A	2	For students to use in mixing salt.
Pitcher of fresh water	1	Station A	2	Tap water is fine.
Pitcher of salt water	1	Station A	2	See Table 1.4a for instructions on making salt water.
Thermometer	2	Station A	4	For students to use in measuring water temperature.
Miscellaneous sinking and floating objects	15	Station A	30	Small vials, BB pebbles, corks, push pins, packing peanuts, marbles, blocks, crayons, chalk, balloons, and paperclips work well.

T-WDS Table 1.6. Station B – Structured Activity. Assuming a class of 32 students divided into groups of four (8 groups), you will have two station Bs.

Materials	Quantity	Per	Total for 2 Station Bs	Notes on Material Number or Material Modification
Laminated copy of Station B Sign	1	Station B	2	
Station B worksheet	4	Station B	8	"Structured Activity Station Instructions"
Identical clear containers	2	Station B	4	Plastic cups or beakers; approximately 12 ounce. Cups or beakers with smooth sides (no ridges) work best.
Large sheet of paper	1	Station B	2	A piece of flip chart paper works well.
Food coloring	1	Station B	2	Any dark color (e.g. blue, green, or red)
Small ice container	1	Station B	2	Small plastic bowl or beaker to hold ice cubes
Ice cubes	2-4	Group to rotate through Station B	16-32	Each rotation through the station will use about 2-4 ice cubes.
Sponge	1	Station B	2	For cleanup.
Towel	1	Station B	2	A rag or hand towel for drying hands and cleaning up station
Small waste container or sink	1	Station B	2	To dispose of used water. A sink may also be used.
Pitcher of fresh water	1	Station B	2	Tap water is fine.
Pitcher of salt water	1	Station B	2	See Table 1.4a for instructions on making salt water.

T-WDS Table 1.7. Station C – Problem-solving Challenge. Assuming a class of 32 students divided into groups of four (8 groups), you will have two station Cs.

Materials	Quantity	Per	Total for 2 Station Cs	Notes on Material Number or Material Modification
Laminated copy of Station C Activity sheet	1	Station C	2	
Identical clear containers	2	Station C	4	Plastic cups or beakers; approximately 12 ounce. Cups or beakers with smooth sides (no ridges) work best.
Large sheet of paper	1	Station C	2	A piece of flip chart paper works well.
Food coloring	1	Station C	2	Any dark color (e.g. blue, green, or red)
Small ice container	1	Station C	2	Small plastic bowl or beaker to hold ice cubes
Ice cubes	2-4	Group to rotate through Station C	16-32	Each rotation through the station will use about 2-4 ice cubes.
Sponge	1	Station C	2	For cleanup.
Towel	1	Station C	2	A rag or hand towel for drying hands and cleaning up station
Small waste container or sink	1	Station C	2	To dispose of used water. A sink may also be used.
Pitcher of fresh water	1	Station C	2	Tap water is fine.
Pitcher of salt water	1	Station C	2	See Table 1.4a for instructions on making salt water.
Thermometer	2	Station C	4	For students to use in measuring water temperature.
Miscellaneous sinking and floating objects	15	Station C	30	Small vials, BB pebbles, corks, push pins, packing peanuts, marbles, blocks, crayons, chalk, balloons, and paperclips work well.

T-WDS Table 1.8. Station D – Read and Answer. Assuming a class of 32 students divided into groups of four (8 groups), you will have two station Ds. Note that station D can also be done as homework prior to, or after, the other stations.

Materials	Quantity	Per	Total for 2 Station Ds	Notes on Material Number or Material Modification
Laminated copy of Station D Activity sheet	1	Station D	2	
Station D worksheet (may be homework)	1	Student	32	"Read and Answer" sheet. Note that two examples of this worksheet are provided to choose from. Note also that if you do not have time in class, you may do this as a homework station.

T-WDS Table 1.9. Station E – Video and Answer (*optional*). Assuming a class of 32 students divided into groups of four (8 groups), you will have two station Es. Note, however, that station E is optional and can also be done as homework.

Materials	Quantity	Per	Total for Station E	Notes on Material Number or Material Modification
Laminated copy of Station E Activity sheet	1	Station E	1-2	
Station E worksheet	1	Student	32	"Questions on the Video" sheet. One example video and worksheet are provided.
Computer(s) or other technology to show video	1	Station E	1-2	You may choose to do station E as a class and use only one TV, projector, or computer to show the video. You may also do station E as a single station or as two stations, depending on your equipment.
Speakers or earphones	1	Station E	1-2	You may choose to do station E as a class and use only one speaker. You may also do station E as a single station or as two stations, depending on your equipment.

Material Explanations

Miscellaneous “sink and float” objects

- These objects are intended to allow students to investigate density differences between fresh and salt water.
- Objects that can be manipulated (made more or less dense) are most effective (e.g. corks with push pins, vials that can be filled, or foam packing peanuts that can be torn apart).
- These objects are intended to increase the mystery, fun, and complexity of the activity; not all of the objects need to be useful.

Ice cubes

- The ice cubes need to be close to the same size and relatively large so that the students will be able to compare results between salt and fresh water.
- Ice cubes from ice cube trays or ice dispensers with large, “half moon” shapes work well.
- Crushed ice will not work.
- A cooler or freezer is needed for storing ice cubes; you can then restock ice cubes between station rotations.

Food coloring

- Dark food colors (e.g. green, blue, red) are more distinctive in water than light food colors (e.g. yellow).

Procedural Modifications

Changing Content Topics

- The overall goals of this activity apply to the teaching of any topic, however the activities are most effective if participants are authentically learning new content themselves.
- This activity uses four challenging water density stations. The activity was designed for relatively high level, from undergraduates to professional scientists. Thus, with younger students, you may need to alter the stations or do a lot of coaching and explaining.
- Ideally, the topic you present would be one you are very familiar with and one that is appropriate for the level of your students and specific to your course.
- All stations should deal with the same topic/content.
- The specific lesson is less important than the focus of the stations and the discussion of learning cycles and TSI phases.

Accommodating Class Time Allotment

- With 10 minute station rotations, you need at least 60 minutes to do all five stations in one period. To accommodate shorter periods, you may choose to:
    a. Introduce the activity and activity stations the day before you do the stations. You can then assign students a homework writing reflection on how they think they learn best, using the inquiry prompts.
    b. Do the reading and writing station (D) as homework. This station takes the longest and is completely paper based.
    c. Skip station E (listen and answer), do as homework, or do the day prior to the other stations as a pre-lesson and/or content front-loading to prepare students for the density station rotations.
- Activity stations. Students should have at least 10 minutes at each station. You may extend station time as appropriate, even extending stations over multiple days. Some example scenarios:
    - A-E all in class
    - A-D in class; skip E
    - A-C in class with D as homework
    - E as preparation, A-C in class with D as homework
    - A-C in class with D & E as homework
    - A-D in class with E as homework

Activity Inquiry Prompts

Learning cycles and TSI phases

1. Think about one of your favorite teachers or a favorite class. Make a list of the things you enjoyed about learning with that teacher or class.
2. Do you prefer activities or labs that have very specific procedures or ones that are more open-ended where you get to design the methods yourself?
3. When you get a new toy or a new piece of equipment, do you read all of the instructions first or do you start trying to figure it out on your own?
4. Do you prefer to read about a topic or have someone else explain it to you?
5. Do you like to know why you need to learn something before you get interested?
6. Do you like learning lots of facts and trivia?
7. Are you good at taking things apart and figuring out how they work?
8. Is the way you learn things at home or from your family different than the way you learn in school? How?

Ocean circulation and salt verses fresh water

9. How would you figure out whether a cup of water was salty or fresh if you couldn’t taste it?
10. Does fresh water sink or float in salt water?
11. Does the salinity of water (fresh or salt) affect the melting speed of ice?
12. How does the salinity of water affect the circulation of water in a pond? In the ocean?

Procedure

1. **Introduce the idea of learning styles and cultural approaches to learning**
   You might share a quote that is special to you or one that is culturally relevant with your class. Two examples from Hawaiian culture follow.
   a. "I ulu no ka lālā I ke kumu" *The branches grow because of the trunk.* (Traditional Hawaiian Proverb; Pukui, 1983). In her translation of this Mary Kawena Pukui points out that "without our source or teacher we would not be here." In other words, it is both the teaching and the learning that perpetuate the sharing of knowledge and the discovery of new knowledge. She further writes in explanation, "Aʻo mai, Aʻo aku - teaching and learning are the same; it's a two-way street."
   b. In the words of Malcom Chun (2006), "Aʻo is the word for education, but it means much more. It implies to learn (aʻo mai) and to teach (aʻo aku). This sense of receiving and giving supports the idea that relationships and belonging are primary actions in traditional Hawaiian society and culture." P.1

2. **Introduce the activity & assign a free-write (may be homework)**
   a. Have participants think about their own learning experiences and then have participants discuss the following with a partner: "Think about one of your favorite teachers or a favorite class. Make a list of the things you enjoyed about learning with that teacher or in that class." (You may also use the other inquiry prompts listed above, or make up your own.)
   b. This may be done the class prior or as homework prior to the station rotations.

3. **Introduce the overall goals of the Activity Stations**
   Students will be rotating through four stations that represent different instructional approaches.
   a. **These stations have been specifically designed for adults**, to stimulate discussion on how people learn. Some students may know a little or a lot about the subject area, but **the purpose is for them to experience these stations as different approaches to teaching a topic of *any* kind**.
   b. **Emphasize that** the **most important objective is to reflect on the learning experience,** although one of their goals is to perform the assigned tasks.
   c. **Encourage students to be aware of how they react personally** to each approach, and how each stimulates, stifles, or in some other way impacts their learning.
   d. **Students will do the activities at each station:** Working in small groups, students will rotate through the stations, following the directions at each station.
   e. **Explain that students will rotate**, with people moving from station A to Station B, and people from B moving to C, from C to D, from D to E, and E to A (or modified according to how many stations you are doing).

f. **Students will clean up the stations:** Students will clean up stations when they are done.
g. **You will keep time.** Students will have about 10 minutes at each station.
h. **It's okay if they don't finish the station.** With the exception of the read and answer stations (which they can do for homework), it's okay if they don't finish the station as long as they were engaged and got the feel for the type of inquiry at the station.

4. Have students rotate through stations

a. Remember to keep time!
- Keep an eye on station B. When most students have finished the structured activity at station B (about 8-10 minutes), announce that it is time to rotate.
- Make sure you will have enough time for students to rotate through each station.

b. **Monitor stations:**
- Check in to make sure students understand the directions.
- Remind students to think about their thinking.
- You may need to help students who struggle with station content.
- You may assign the reading and writing station (D) or the listening and answering station (E) as homework.

5. Hand out Station C explanation

a. Have students read the explanation
b. Hold a class discussion to be sure students understand that differences in density caused the ice cube to melt slower in salt water by creating an insulating, fresh water layer of water around the ice cube.

6. Debrief of Station Activities

This discussion may happen the day following the station rotations.

a. **List station titles on paper or a chalkboard in front of the room**

A: Open-ended Exploration
B: Structured Activity
C: Problem-solving Challenge
D: Read and Answer
E: Video and Answer

b. Ask the participants to reflect on their responses to the activities and discuss the strengths and weaknesses of each approach
- Draw their attention to Station A, Open-ended Exploration, and ask for their reactions. How did it make them feel? Did they learn from it?
- Be prepared for (and welcome) some disagreement. If only positive reactions to the station are brought up, ask if anyone had a negative reaction, and vice versa.

- Point out that in this example, the Open-ended Exploration station was intentionally unstructured in an *exaggerated* fashion, in order to provoke reaction and discussion. Exploration need not be completely unstructured. More specific procedural directions, data recording charts and debriefing discussions can make it a more rewarding and educational experience for all learners.
- Do the same debrief with stations B, C, D, and E.

c. **Do a vote for favorite stations, and discuss participant preferences**
  - Point out and discuss any interesting trends that may emerge in your class.
  - Tell students that individuals often have different teaching approach preferences. This preference is guided by their own comfort level in learning via a given approach. Preferences may have to do with individual learning styles or with prior experiences with different teaching approaches.
  - Ask students how the stations relate to their past experiences in their science classes.
  - Ask student how the stations relate to the way they learn at home.
  - Ask students to keep in mind that not all learners function best with their personal favorite approach. Some groups (and individuals) may need more guidance than they would like to keep their learning goals on target. Other students may benefit from more time to explore on their own, struggling with content more than they would like, in order to achieve conceptual understanding.

d. **Ask students to suggest some possible goals related to different teaching approaches**
  - You can record student ideas on the board or on large poster paper.
  - Point out that educator's choices for different approaches can often depend on the goals of the lesson.
  - Ask what goals each type of approach might serve. Use the following lists to supplement discussion as needed:

A. Open-ended Exploration

- Introduce learners to a new subject area
- Generate questions
- Generate learner interest and foster positive attitudes about science.
- Encourage learners to work together without direct educator intervention
- Develop and identify concepts, processes and skills, raise questions and problems
- Provide a common base of experiences
- Practice observation skills

B. Structured Activity

- Introduce concepts, vocabulary, processes, skills and investigation methods
- Guide learners toward specific discoveries
- Provide a common base of experiences
- Provide successful activities with predictable outcomes

C. Problem-solving Challenge

- Model what scientists do
- Provide a sense of accomplishment
- Challenge learners' conceptual understanding and skills by applying them to new situations
- Develop deeper and broader understanding through real world applications

D. Read and Answer

- Provide specific content information and vocabulary on a topic
- Extend the information from an activity into descriptions of related experiences that are impractical in a classroom setting
- Provide alternative explanations and make connections to other disciplines

E. Video and Answer

- Extend and demonstrate information from a topic via visual descriptions of related experiences that are impractical in a classroom setting
- Make connections to other disciplines
- Show real-world examples and application
- Allows experts who are not readily available explain phenomenon

e. Note other factors that may impact teachers' choices

- Point out that choices of teaching approaches also depend on available time, home and school culture, and the previous experiences of the audience and the educator.
- Discuss how teachers try to use a balanced diet of teaching approaches because of different learner preferences. Sometimes students may be asked to learn in a way they do not prefer. If is important to remember that other students might prefer something different, and it is important to try to be engaged in all kinds of ways of learning.
- Point out that even if one way of learning is easier for your students, they need to learn to adapt to situations where the teacher (or lack of teacher) is not suited to their "preferred learning style". Examples of this include students wanting to learn how to put together a new desk, learning a computer program, learning to drive, learning online, etc.

f. Introduce the idea of learning cycles

- Point out that each group rotated through the stations in a different sequence.
- Ask if they like the order they did the stations in, or if there is a different order they think would have suited them better or been more effective.
- Explain that lessons and units are usually planned to follow a learning cycle but that all students don't proceed through the learning cycle in the same way.
- Make connections to traditional ways of knowing and the scientific process.

g. Connect the structure of this activity with the phases of inquiry

- Introduce the TSI phases of Inquiry
- Discuss and assign activity stations to the phases.
- Note that many lessons suffer as a result of a focus on only one phase of a learning cycle because teachers feel most comfortable in that phase.

h. Show that there are different perspectives that you can use to look at the TSI phases of learning and inquiry

- A whole unit might be made up of activities that each target a phase
- A lesson might be made up of steps/parts that each target a phase
    a. Show students your learning plan for the activity
- A student may go through many phases within one activity step
    a. Have students (in their groups) plot their path through the phases for one of the stations

i. Assign a homework reflection

- Ask students to write a commentary on their perceptions of the exercise and which inquiry phase they enjoyed most.
- Ask students to comment on their preference for visual, auditory, written, or hands-on lessons.
- Ask students how they can use what they have learned to take ownership of their own learning, including the ability to recognize and adapt in situations when information is not being offered in a way that is preferable to them.
    - Can they initiate themselves?
    - Can they take notes during lectures so they can see words or pictures if they are more visual?
    - Can they listen to a book rather than read it if they are more auditory?

Further Investigations: Teaching Science as Inquiry (TSI) Phases of Inquiry

1. Students can complete western-style learning style inventories (e.g. Kolb, 1984) and describe their learning preferences as a starting point for comparing cultural difference in learning, teaching, and understanding about the natural world.

2. Have a class discussion about the different ways in which people learn. Ask students to comment in writing about their own learning preferences and the influence of their cultural traditions on the way they learn in general and science in particular.

3. Have a neurologist, psychologist, education, and/or cultural expert come talk to the class about the different way that people learn. Compare what these expert presenters say about how people learn with the way that scientists accumulate knowledge about the world. What are the similarities and differences?

Answers to Questions

Worksheet for Station D Option 1

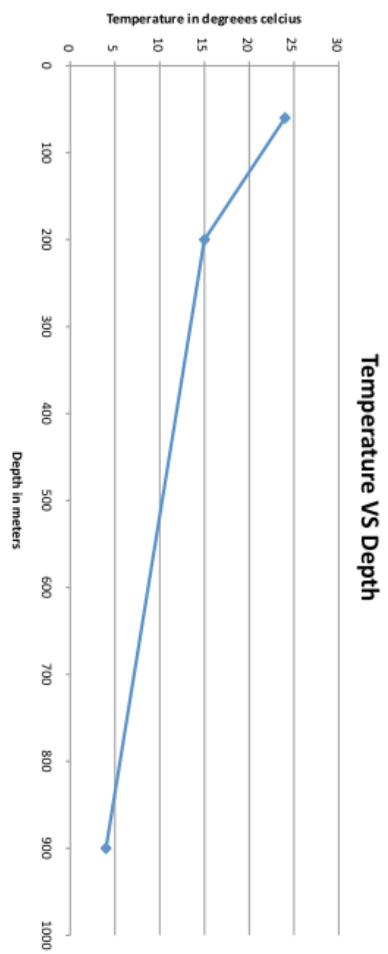
Page 1

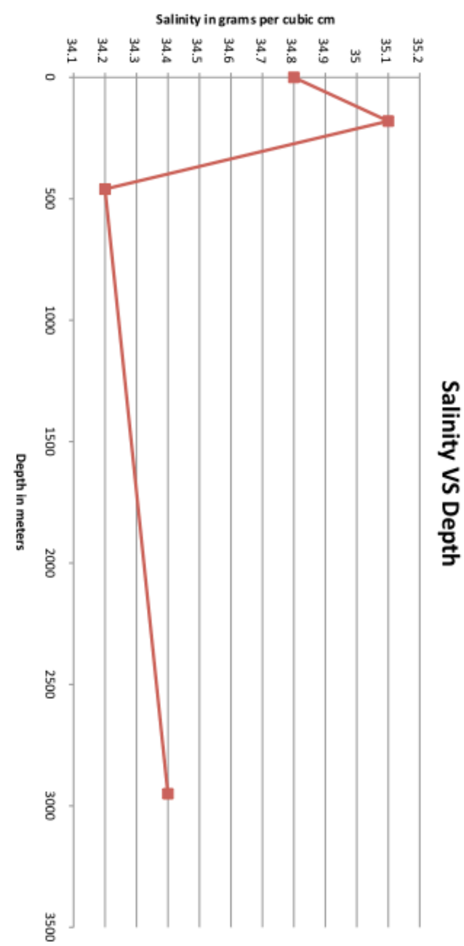
1. From the reading, determine three data points for temperature and four data points for salinity at different depths.

Temperature in °C	Depth in m
24	60
15	200
4	900

Salinity in g/cm^3	Depth in m
34.8	0
35.1	180
34.2	460
34.4	2,950

2. Based on the data, make graphs of temperature v. depth and salinity v. depth.





3. Describe the trends in temperature and salinity in the water column.

Salinity is low at the surface, gets higher, and then lower, then higher again with depth. Temperature is more regular and trends down with depth.

4. How could you explain these trends?
   In the salinity profile, salinity might be less at the surface due to fresh water runoff.
   In the temperature profile, temperature decreases with depth because the deeper down, the farther the water is from sunlight.

5. How does the water column off of Kahe Point relate to water layers along the Wai'anae coast?
   They are in close proximity and very similar. From the reading, "Although Kahe Point is just outside the southern extent of the Wai'anae moku, information and data collected at Kahe Point can be considered relevant to the Wai'anae coast."

6. What further questions about temperature, salinity, or water layers do you have after reading this article?
   Answers will vary. Students may wonder why the water mixes in the upper water column (mostly due to wind and similar density) or why salinity is slightly less in the mid water column.

Answers to Questions

Worksheet for Station D Option 2

1. Why is seawater more dense than pure water?
   Seawater is more dense than pure water because it has substances (mostly salts) dissolved in it. In other words, seawater has more stuff (water molecules + salts) packed into the same amount of space.

2. How are water layers formed in the ocean?
   Water layers are formed by differences in density. Temperature is a big driver of density differences in the open ocean, but near shore freshwater runoff can also help form layers.

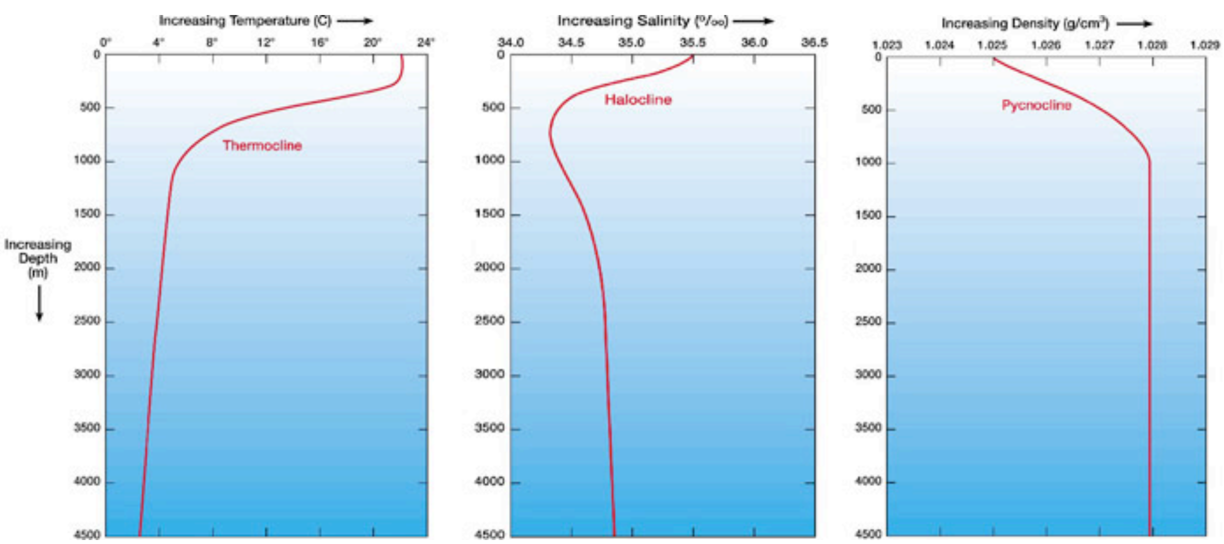
3. What further questions about temperature, salinity, or water layers do you have after reading this article?
   Answers will vary. Students may wonder about ice or about the effect of pressure. Students might also wonder about other aquatic environments, such as lakes.

Answers to Questions
Worksheet for Station E (Optional)

1. The transition zone is a boundary layer between the warm surface layer and the cooler deep ocean water. What physical properties change in the transition zone? The transition zone is normally marked by changes in salinity and temperature.

2. Research vessels use instruments to measure properties of water. What are these instruments called? What variables are measured by these instruments?
   A CTD. It stands for, and measures, Conductivity (which is used to estimate salinity, Temperature, and Density. Modern CTDs also measure light and pressure.

3. Define thermocline and pycnocline.
   A thermocline is a region where water temperature decreases rapidly with increasing depth. A pycnocline is a region where density increases rapidly with depth. Water below the pycnocline is usually cold and dense. Because temperature decreases with depth, and as temperature decreases density increases, thermoclines and pycnoclines are usually related, but opposite (lower temperature, higher density).



Images from http://www.hurricanescience.org/science/basic/water/ showing corresponding rapid changes in temperature (thermocline), salinity (halocline), and density (pycnocline).

4. What unit is used to measure density?
   Density is measured in mass per volume, commonly in g/cm^3.

5. At What temperature is water the densest?
   Water is most dense at about 4^oC (3.98^oC, to be exact).

6. How does ocean stratification determine where organisms live? What characteristics allow organisms to live in the surface layer but not in the deep ocean?
   Stratification can affect where organisms live by either keeping them apart (if they are unable to move through the water layers on their own power) or by providing habitat/environmental qualities preferable to particular organisms. For example, light, warmth, and oxygen are often more abundant in surface layers.

Station A Activity sheet

Station A Open-ended Exploration

Examine the materials on the tray. Using only those materials, devise experiments you can perform to learn as much as you can about:

- **The characteristics of warmer vs. cooler water**
- **The characteristics of salty vs. fresh water**
- **The relative densities of different temperatures and salinities of water**
- **Density-driven currents in the ocean**

And remember, this is a science classroom—no tasting!

Station B Activity sheet

Station B Structured Activity

Follow the procedures described on the worksheet provided. You are allowed to work as a group to conduct the activity and to arrive at your answers.

Station B Worksheet

Instructions and worksheet for Station B
Structured Activity

1. Find two beakers of water on the table. One is labeled “salt water,” the other is labeled “fresh water.”
2. If you place the same number of ice cubes in each cup at the same time, which do you predict will melt the fastest? Why?

3. Now place three ice cubes in each beaker of water. Observe both for 90 seconds. Do not stir or disturb the ice cubes or take them out of the water. Allow them to continue to melt in the beaker as you complete this station.
4. Observe the ice cubes in the beaker. Which ice cubes melted the fastest?

5. What is your evidence?

6. Gently add 4 drops of food coloring to each beaker right on top of the ice cube without stirring or otherwise disturbing the water. Describe your observations.

7. Explain what you think is happening.

Station C Activity Sheet

Station C Problem-solving Challenge

- There are two beakers of water on the table. One contains salt water, the other fresh water.
- Using only the materials at the table, devise an experiment that you can perform right now that will reveal which is the salt water.
- Record your experiment (design, procedures) and the results.
- Describe the evidence that you collect and how it supports your determination of which is the salt water.

No tasting allowed!

Station C Worksheet Handout

"Mystery Water" – What Happened and Why?

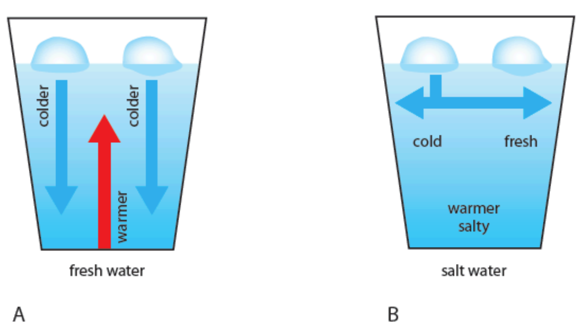
Ice melts faster in fresh water than in salt water.
It's all about density!

Ice in fresh water (T-WDS Fig. 2.2 A)
Water from melting ice is cold and fresh. It is more dense than fresh water at room temperature (remember that as temperature decreases water density increases). Dense cold water from the melting ice mixed with food coloring sunk to the bottom of the cup.

When the dense cold water sank to the bottom of the cup, it displaced water at the bottom of the cup. The room-temperature water at the bottom of the cup had to go somewhere when it was pushed out of the way by the sinking cold water. The displaced room-temperature water from the bottom of the cup moved up toward the surface. Eventually, the movement of dense cold water sinking and room-temperature water being displaced mixed the food coloring throughout the cup.

The result of this mixing process was that the ice was always being surrounded by new room-temperature water as the dense cold water sank and less dense room-temperature water was pushed upward. Therefore, the ice melted faster in fresh water.

Ice in salt water (T-WDS Fig. 2.2 B)
Water from melting ice is cold and fresh. Fresh water is less dense than salt water no matter what the water temperature is (remember that water density decreases as salinity decreases). Since the cold water from the melting ice was less dense than the salt water, it floated on the top of the salt water. This is why the food coloring formed a layer at the top of the cup. The layer of cold water from the melting ice "insulated" the ice. In other words, the cold, fresh water from the melting ice helped keep the ice cold. Therefore, the ice melted more slowly in salt water.



T-WDS Fig. 2.2 (**A**) Ice melting in room temperature fresh water (**B**) Ice melting in room temperature salt water

Station D Activity Sheet

Station D
Read and Answer

Read the information sheet and answer the questions.

Station D Worksheet Option 1
Think about what you are thinking as you read. To help you think you can underline or highlight main ideas or write in the margins.

Water Column-Kahe Point, O‘ahu
A water column profile is a cross-sectional view of the sea. The profile describes changes in the physical, chemical, and biological features of seawater with depth, and serves as a foundation for understanding ocean and coastal processes such as the currents and productivity in the sea. The water column profile for the area off Kahe Point was studied extensively in the 1980s as part of the proposed (but never built) 40 megawatt (MW) Ocean Thermal-Energy Conversion plant. Although Kahe Point is just outside the southern extent of the Wai‘anae moku, information and data collected at Kahe Point can be considered relevant to the Wai‘anae coast.

Temperature and Salinity
The temperature and salinity (salt content) of seawater are important attributes of the water column profile. Temperature and salinity gradients define different layers in the water column and indicate the boundaries of different water masses off the Wai‘anae coast. This helps scientists determine water movement near the Hawaiian Islands. The mixed layer of the ocean off the Wai‘anae coast extends from the surface to depths of about 30 to 60 meters (100 to 200 feet).

In the mixed layer, temperature is nearly uniform with depth. Below the mixed layer is the thermocline, the layer in which seawater temperature declines rapidly with depth. In the thermocline, seawater temperature decreases from about 24 degrees centigrade at a depth of 60 meters (200 feet) to 15 degrees centigrade at over 200 meters (650 feet). Below this depth, temperature decreases gradually. At 900 meters (2,950 feet) depth, seawater temperature off Kahe Point is about 4 degrees centigrade. Surface water salinity off Kahe Point is about 34.8 parts per thousand (ppt), typical of the Pacific central water mass. This low-salinity warm surface layer grades into the underlying Pacific intermediate water mass, which is characterized by a maximum salinity of 35.1 parts per thousand (ppt) at 180 meters (600 feet) and minimum of 34.2 ppt at 460 meters (1,500 feet). At 900 meters (2,950 feet) depth, seawater salinity off Kahe Point is about 34.4 ppt.

Station D Worksheet Option 2

Questions
1. From the reading, determine three data points for both temperature and four data points for salinity at different depths.

Temperature in °C	Depth in m

Salinity in g/cm^3	Depth in m

2. Based on the data, make graphs of temperature v. depth and salinity v. depth.

3. Describe the trends in temperature and salinity in the water column.

4. How could you explain these trends?

5. How does the water column off of Kahe Point relate to water layers along the Wai‘anae coast?

6. What further questions about temperature, salinity, or water layers do you have after reading this article?

Excerpted from:
http://hawaii.gov/dbedt/czm/initiative/wec/html/sea/ocean/profile.htm

Station D Worksheet Option 2

Think about what you are thinking as you read. To help you think you can underline or highlight main ideas or write in the margins.

Water Density

Density is a property of all substances and is the ratio of the mass of a substance to its volume: **density = mass / volume.** In aquatic systems water density plays an important role in structuring the environment and in determining how water moves.

Pure water

By definition, the **density of pure water at 4°C is 1 gram per cubic centimeter** (cm^3; note: 1 cm^3 = 1 ml). Most substances become more dense as they cool, but water is unusual in this respect. The density of liquid water increases as it cools down to 3.98°C, but as cooling continues the density of water decreases. The hydrogen bonds between water molecules form a framework and cause the liquid to expand slightly. When water crystallizes into ice at 0°C, its density decreases abruptly due to the rigid framework formed by hydrogen bonds. As ice cools to below 0°C its density increases, but ice is always less dense than an equal volume of water. Since ice is less dense than water, ice “freezes over” as a floating layer instead of “freezing under” or freezing from the bottom like most other liquids.

Seawater

Seawater is a solution of pure water and dissolved materials. A liter of seawater weighs between 2% and 3% more than a liter of pure water and is therefore more dense. Most materials dissolved in seawater are ions (positively or negatively charged atoms and molecules) that form solid salts when the water is evaporated. **Salinity** is the total mass of salts (in grams) in 1,000 grams of seawater and is commonly expressed in terms of **parts** (of salts) **per thousand** (parts of seawater). For example, ocean water, which has 35 g of salts dissolved in 1000 g of seawater, has a salinity 35 parts per thousand or 35‰. (Scientists now measure salinity as a conductivity ratio using the Practical Salinity Scale.).

Ocean stratification and density-driven circulation

Ocean water tends to form into stable layers with the least dense water at the surface and the most dense water on the bottom. In the open ocean, salinity does not vary to a great extent, and density stratification is determined primarily by temperature. In coastal areas and bays, in contrast, salinity can vary significantly due to inputs of freshwater from rivers and land run-off, and density stratification may be determined primarily by salinity. The greater the difference in density between the surface and bottom waters the more stable the water column is and the harder it is to mix surface water down to depth or deep water up to the surface.

Density differences between water masses drive deep-ocean currents. In some regions of the ocean, dense water masses form at the surface (e.g. polar regions like the Norwegian Sea and Weddell Sea). These dense water masses sink and displace less dense water underneath. This density-driven circulation is called **thermohaline circulation** (“thermo” = heat; “halos” = salt). Virtually the entire ocean is involved in thermohaline circulation, a slow process that is responsible for most of the vertical movement of water in the ocean and for the circulation of the ocean as a whole.

Questions

1. Why is seawater more dense than pure water?

2. How are water layers formed in the ocean?

3. What further questions about temperature, salinity, or water layers do you have after reading this article?

Excerpted from:
http://hawaii.gov/dbedt/czm/initiative/wec/html/sea/ocean/profile.htm

Station E Activity Sheet

Station E

Watch the video. Answer the questions.

CMORE Hawaii "Water Stratification – Narrated"
http://cmore.soest.hawaii.edu/education/teachers/science_kits/ocean_conveyor_kit.htm

Station E Worksheet

Worksheet for Station E
Questions to answer on “Water Stratification”

7. The transition zone is a boundary layer between the warm surface layer and the cooler deep ocean water. What physical properties change in the transition zone?

8. Research vessels use instruments to measure properties of water. What are these instruments called? What variables are measured by these instruments?

9. Define thermocline and pycnocline.

10. What unit is used to measure density?

11. At What temperature is water the densest?

12. How does ocean stratification determine where organisms live? What characteristics allow organisms to live in the surface layer but not in the deep ocean?