



## Chapter 9. Are Cold Liquids More Dense Than Warm Liquids? A Guided-Inquiry Activity

### Think About This!

Have you ever been in a very warm room on a very cold winter day and opened a door or window leading to the outside for a short period of time? What did you experience as you stood in the opened doorway or near the opened window? Did you experience a rush of cold air past you as you stood there? What do you think might explain this rush of air into the room? What if you had been on the outside in a similar situation and opened a door into a warm room. Do you think you would have experienced a rush of warmer air past you to the cooler outside? Why? Why not?



### Probing Further

An important concept in meteorology has to do with the difference in the weight of cooler air compared with the weight of warmer air. This difference helps to set up important dynamics in the atmosphere. Verifying that warmer air is lighter than cooler air helps to take some of the abstractness out of developing a basic understanding of weather. Using simple equipment, it is very difficult to design experiments to test this concept with gases.

However, liquids have many of the same physical properties as gases with regard to the dynamics of flow and movements. In science, it is often necessary to project findings from one set of materials or situations to another. This projection is valid only if the physical properties being studied are very similar. Because of the similarity of the fluid dynamics of both liquids and gases, the following activity will use water in the liquid form to better understand some of the properties of gas in setting up dynamics in the atmosphere.

### Objectives for the Learner (Essentials of Inquiry)

**Conceptual Theme:** To develop a basic understanding of some of the movements that take place when warmer water and cooler water interface, and probing the dynamics resulting from this interaction.

**Content:** Developing basic information relating to the flow of liquids and gases, relating to differences in densities to variations in temperature and the process setting liquids and gases in motion. Further, providing a basic understanding of other factors that constitute the study of meteorology.

**Skills:** The focus is on using laboratory equipment, making careful observations, recording physical changes, drawing conclusions and describing and communicating results. This activity is important because the student will learn about experimental design procedures.

**Scientific Habits of Mind:** The importance of careful observations, respect for data, and verifying results.

## Materials

Large clear plastic container  
(shaped like a shoe box is ideal)

Cold water

Container for holding 100 ml of  
cold water

Non-mercury thermometer

Ice cubes

Stirring rod

Food coloring



## Preparation

In the preceding activities, the student was given both the question to investigate and the procedure for carrying out the investigation. In the confirmation-verification activity, the student had a concept of the outcome before conducting the activity. In the structured-inquiry activity, the conclusion was based upon the data generated by the activity.

## Shifting the Learning Responsibility to the Learner

*As the teacher shifts learning from a teaching process to a facilitating process, the level and quality of guiding questions are of utmost importance. Questions are used more to help guide the learner's thinking as opposed to eliciting answers. Dennis Palmer Wolf, in "The Art of Questioning," published by Academic Connections in 1987, suggests that there are four major types of questions:*

**Inference Questions:** *These questions ask students to go beyond immediately available information, asking them to find clues, examine them, and to discuss what inferences are justified.*

**Interpretation Questions:** *Where inference questions demand that students fill in missing information, interpretive questions propose that they understand the consequences of information or ideas.*

**Transfer Questions:** *Where inference and interpretation questions ask a student to go deeper, transfer questions provoke a kind of breadth of thinking, asking students to take their knowledge to new places.*

**Questions about Hypotheses:** *These questions are useful in making students actively aware of their expectations because they are based on what can be predicted and tested. Typically, questions based on what can be predicted and tested are thought of as belonging to sciences and other "hard" pursuits. But, in fact, predictive thinking matters in all domains.*

*With guided inquiry, more of the responsibility for learning is shifted to the student. The teacher becomes more of a teacher for the learning. One of the most challenging issues for the teacher is to help the student arrive at a procedure through guided discussions. DO NOT TELL THE STUDENT THE STEPS IN THE PROCEDURE. TOO MUCH SPECIFIC DIRECTION FROM THE TEACHER WILL "TALK THE INQUIRY" OUT OF AN INQUIRY ACTIVITY.*

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*In guided inquiry, it is necessary for the student to design an appropriate procedure to collect the necessary data to resolve the question. It is important that the student not be given the procedure and that he or she be encouraged to be creative and innovative in designing a procedure. The important part of the design must be one that will produce appropriate and valid data to resolve the question.*

*There are perhaps many procedures that could be designed to resolve the question. One such procedure is outlined below. It is important not to give this procedure to the students but rather guide them in arriving at this or a similar design. The list of materials that has been suggested will help form and put parameters on the design. After understanding the design and what is to be accomplished, the teacher should feel free to add additional materials that will enrich the student design. One of the most important outcomes of this activity is the student designing the activity.*

*In this activity, some assumptions are made about temperature and density. It is assumed that the cooler water is denser (heavier) than the warmer water. Thus, if this assumption is correct, and if the procedure outlined below is followed, the colored water should sink down through the warmer water toward the bottom of the container. In this activity, depending on the water temperatures, it is possible that the colder food-colored water will settle on the bottom of the container and form a layer of colored water. Another assumption is that air will follow a similar pattern in the atmosphere. Make certain that students understand the consequences (scientific habits of mind) of projecting the fluid dynamics of liquids (water) to the fluid dynamics of gases (air) to better understand the dynamics of the Earth's atmosphere.*

## **Procedure**

*Place the clear plastic container on a level surface and fill with warm water until half full.*

*Place ice in the 100 ml container and fill half full with water.*

*Stir the ice and water to cool the water.*

*Add a dark food coloring (red or blue) to the cool water and mix it well. Keep adding food coloring until the water is very dark.*

*Use the thermometer to check the temperature of the colored water and record this temperature.*

*Use the thermometer to check the temperature of the water in the clear plastic container and record this temperature.*

*Carefully pour small amounts of the colored water into the clear plastic container, as shown in Figure 9-1 and observe and record the results. If possible, the drops should be added using a dropper or some other method to avoid adding momentum by "dropping" the drops into the water. This will make the experiment more realistic.*



**Figure 9-1. Container of water after adding colored water.**

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## **Examining Results**

### **Background for the Teacher**

*In this activity, the teacher must fulfill the role of teacher of learning. This role demands less emphasis upon dispensing information and an increased role of drawing from the learner the information necessary to complete the design of a temperature inversion in the atmosphere where warm air forms a layer above cooler air.*

*Discuss the challenge, designing a procedure similar to or better than the subsequent activity.*

*The key expectation for the student is to design the procedure to determine if cold liquids are heavier than warm liquids. The experimental design should be specifically and appropriately derived so that it will produce data that will resolve the question. Further, it is important that an appropriate conclusion be drawn from the results of the activity. It is expected that the learner will find out that the colder liquid sinks through the warmer liquids and thus strongly suggesting that cold liquids are heavier than warm liquids. A discussion should ensue that will help the learner understand that the dynamics of fluids (water and air) have similar properties and characteristics. This fact is important because air cannot be manipulated as easily as water. The learning must be successfully transferred to the dynamics of air in the atmosphere and setting up important circulation patterns.*

## **Going Further**

*Students might be challenged to experiment with other safe liquids to help confirm the similarity of the dynamics of liquids. (The teacher must become versed in helping students think of other designs.)*

### **Challenge**

*An interesting modification of the activity is to reverse the temperatures by having cold water in the larger container and adding food coloring to the warmer water instead. Trying to pour the warmer water down through the colder water will sometimes result in the warmer food-colored water sinking part way and then returning to the top. This is very similar to air motion.*