Lesson 2.1

How Long Does It Take?

Teaching Focus: Using Guided and Open Inquiry

Inquiry into authentic questions generated from student experiences is the central strategy for teaching science.

National Science Education Standards

NSES CONTENT STANDARD, 5–8: PROPERTIES AND CHANGES OF PROPERTIES IN MATTER

"A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample" (National Research Council, 1996, p. 154).

DESCRIPTIVE OBJECTIVE

Students will design and carry out investigations to determine that different factors such as temperature and surface area affect the rate at which sugar dissolves.

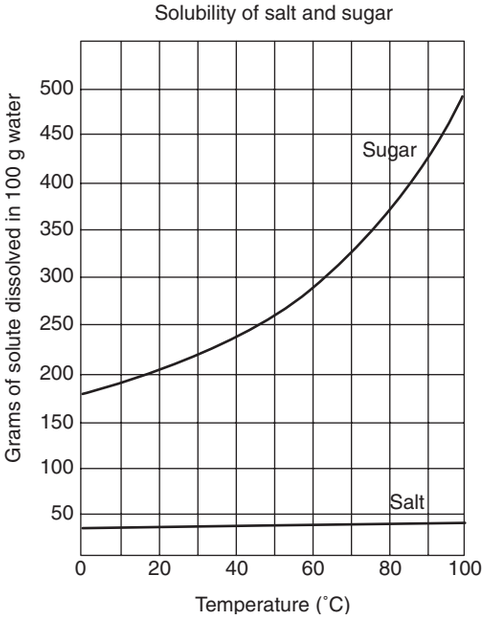
MATERIALS

For each group of students provide sugar cubes, plastic cups, plastic spoons or stir sticks, water of different temperatures (a cold refrigerated pitcher of water [about 5°C]; a warm pitcher of water at room temperature [about 20°C]; hot tap water, but NOT hot enough to burn one's hands [about 45°C]), measuring cups or graduated cylinders, and a stopwatch or clock for keeping time. Students may request additional items when testing their ideas.

SCIENCE BACKGROUND

The substance in greater concentration is known as the solvent and the one that is being dissolved is the solute. Dissolving occurs because of electrostatic attractions between atoms, ions, or molecules—in this case, between water (solvent) and sugar (solute) molecules. The attraction between sugar and water molecules is rather strong, which is why you can dissolve so much sugar in water. The water molecules essentially pull the crystal lattice of the sugar apart, which brings more sugar molecules into contact with water molecules. Increasing the contact between the water and sugar serves to increase the rate at which the dissolving takes place. Thus, stirring increases the rate of dissolving as does crushing the sugar into smaller pieces.

Figure 2.1.1 Solubility for salt and sugar in water



Increasing the temperature adds to the kinetic energy of the molecules and thus increases their motion. The faster the water molecules move, the more often they come in contact with the sugar molecules. This results in more sugar being dissolved. In general, a greater amount of solute will dissolve at higher temperatures. Not all solutes dissolve as readily at higher temperatures as sugar, however. For example, while more salt (NaCl) will dissolve at higher temperatures, the difference is less noticeable. In other words, the solubility curve, as shown in Figure 2.1.1, is flatter for salt than it is for sugar.

MISCONCEPTION INFORMATION

Solubility can be a difficult topic for students because they cannot observe what is happening at the microscopic level. Therefore, you may find many misconceptions including:

- Sugar melts when mixed with water.
- In general, melting is the same as dissolving.
- Sugar transforms into water when it dissolves.

For additional information, you may wish to refer to:

Stavy, R. (1991). Using analogy to overcome misconceptions about conservation of matter. *Journal of Research in Science Teaching, 28*(4), 305–313.

Taylor, N., & Coll, R. (1997). The use of analogy in the teaching of solubility to pre-service primary teachers. *Australian Science Teachers Journal, 43*(4), 58–64.

CLASSROOM SAFETY

Students should be cautioned not to ingest any of the materials. Check the temperature of the hot tap water yourself before allowing students to use it.

Teaching Focus

Defining Inquiry

"Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (National Research Council, 1996, p. 23). In short, inquiry is asking and answering a question about the natural world. It is not the scientific method or any other step-by-step process that scientists or students follow.

Guided inquiry usually refers to a method of investigation that begins with a specified question and some suggestions or guidelines for answering the question. Open inquiry, or full inquiry as noted in the NSES (National Research Council, 1996, p. 122), usually refers to students developing a question and a process for finding the answer as well as carrying out the investigation by collecting evidence, formulating the answer, and sharing the results with others.

It is interesting to discuss individual definitions of inquiry with fellow educators. In 2002 the National Science Teachers Association and Charles Barman asked teachers to do exactly that. They found that teachers held a wide range of different views as to the meaning of inquiry. "Common responses included involving students in activities or investigations, engaging students in problem solving, and having students ask questions about the world in which they live" (Barman, 2002, p. 8).

ENGAGE

Display the materials. Ask the following question: **How does stirring affect how fast sugar dissolves?** Collect and display the students' predictions. Conduct the activity as a demonstration if desired.

Help the students as a class list factors that might affect how fast sugar dissolves. Ask students to tell why they think each factor will change the rate at which the sugar cube dissolves. Record explanations for each factor. Some ideas that students might generate are stirring, different temperatures, crushing the cube, different amounts of water, or different liquids. Save the explanations until the end of the lesson and have the students compare them to the results of their investigations.

Teaching Focus

Inquiry Begins with Ideas for Investigations

To learn how to conduct scientific inquiry, students must move away from confirmation lab activities that demonstrate the information they already know. Have students generate their own ideas before performing a lab activity so that they will be more likely to investigate a question to which they don't know the answer. Also, having students generate ideas will enable you to access and assess their prior knowledge on the topic.

Be sure to focus the students' thinking on the question as they begin this section of the lesson. Remind students that the purpose of the investigation is to find evidence that they can use to answer this question.

Teaching Focus

Starting a Lesson with Guided Inquiry

Martin notes that in guided inquiry, "teachers facilitate children in their investigations of teacher established topics in ways that are comfortable to the children and that also stimulate children to ask and investigate additional questions suggested by the original explorations" (Martin, 2003, p. 207). Because teachers tend to teach in the way that they were taught, and most were not taught with inquiry, they are often uncomfortable teaching science in this way. One way to help ease this transition for both teachers and students is to start a lesson with guided inquiry. Guided inquiry makes teachers and students more adept at generating appropriate inquiry questions and investigations.

EXPLORE

1. Ask the students to identify materials they will need for their investigation. Talk about units of measurement that they will use. For the Explore phase, students will probably use the units of seconds to measure time. The sugar is measured in units of cubes. Emphasize accuracy and organization of data. Help the students design a table which to record their measurements. Table 2.1.1 shows a typical data table.

Table 2.1.1 Effect of Stirring on Solubility Time

	Trial 1 Time	Trial 2 Time	Trial 3 Time	Average Time
Stirring				
No stirring				

Teaching Tip

Organizing Data

Often lab activities have sample charts that students will fill in as they collect their data. Although these can help structure an activity, they also limit students' thinking. Create opportunities for students to think through the processes of deciding what observations and data to collect, how to organize the data, and also how to best represent it. Until students become proficient these processes will take considerable time. The benefits for students' higher order thinking abilities are significant, however.

2. Circulate among the student groups. Ask them questions about their investigation: What question are you investigating? What parts of this investigation are the same as the one in the Engage activity? What is different? Why? Compare the results and explanations of the groups. Ask the students to justify their conclusions using evidence.

TEACHING FOCUS

Focusing Students on the Explorable Question

One of the authors recalls asking a fourth grader engaged in a science investigation to "tell me a little about what you're doing" and getting the response, "step three." No amount of probing gave the student any idea what question she was trying to answer. For this reason it is important to be sure students are focused on the purpose of the investigation before they begin. They should know that they are trying to answer some question(s).

EXPLAIN

1. Students should write a concluding statement to answer their explorable question, using the evidence they have collected.
2. The stirred sugar solution will dissolve faster than the unstirred solution. Discuss these results and explanations with the class. Stirring continually replaces saturated water near each particle of sugar with unsaturated water, thus increasing the rate of dissolving. An interesting question to ask at this time would be whether the rate of dissolving would change if you varied the speed of the stirring. You may want to have students investigate this idea.

EXTEND

1. Have the student groups choose another from their original list of factor that might affect how fast a sugar cube dissolves. The rate at which sugar dissolves in water is determined by such factors as the amount of water, water temperature, stirring the water, and surface area of the sugar (cube vs. crushed). You can eliminate the need for thermometers by preparing pitchers of hot, warm, and cold water ahead of time. Test the hot tap water yourself to make sure it is not too hot.
2. Question students about their plan. Ask them about the evidence they are seeking. How will they observe, measure, record, and organize their data? Check to see that they are manipulating only one variable at a time.
3. Each group can report their findings and conclusions to the class. Encourage the use of evidence to support conclusions.
4. Students should find out the results of other groups and record this information. Sample results are given in Table 2.1.2.
5. Have students write a statement that summarizes all of their knowledge about the different factors that affect how sugar dissolves. This will help them organize all of their information on the solubility of sugar.
6. Have students compare their new knowledge with their prior knowledge from the beginning of the lesson to see which ideas they have modified and which they have kept the same.

TEACHING FOCUS

Follow Guided Inquiry with Open Inquiry

As previously stated, open inquiry refers to investigations in which students generate the questions that they investigate. Guided inquiry can help students develop the skills needed to do open inquiry. When open inquiry follows a guided inquiry, students continue to use some of the same processes, materials, and thinking that they used in the guided inquiry. This method allows the open inquiry investigation to run more smoothly with fewer classroom management concerns for the teacher.

Table 2.1.2 Sample Student Results

Factor Tested	Results
Amount of water	More sugar will dissolve faster as the amount of water increases.
Water temperature	More sugar will dissolve faster as the temperature of the water increases.
Surface area	Sugar will dissolve faster as surface area increases.

APPLY

Discuss individual plans. Make sure student plans for investigations are consistent with what they learned in the lesson. Look for proper use of variables such as stirring, water temperature, and crushing the tablet. This application activity can also be used as an authentic assessment.