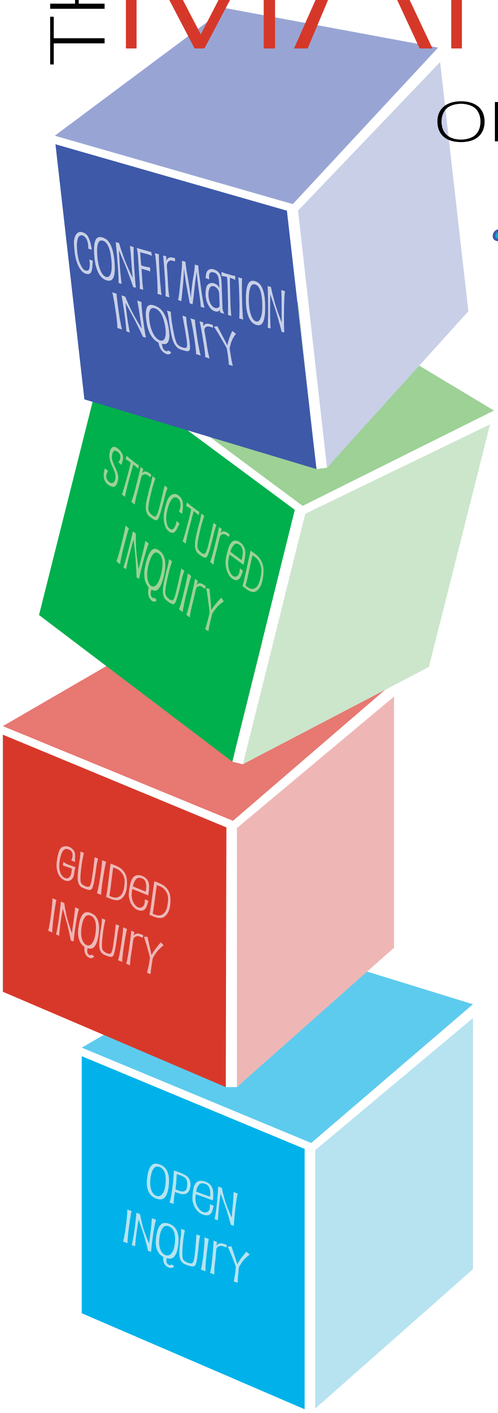
THE MANY LEVELS OF *Inquiry*



Inquiry comes in various forms.

By Heather Banchi and Randy Bell

Elementary teachers often struggle with how to design and implement inquiry instruction with their students. For many, just understanding what inquiry is can be difficult, let alone designing activities that support high levels of inquiry. In this article, we present a continuum by which to evaluate an activity's level of inquiry. Then, using a fifth-grade unit exploring sinking and floating, we describe examples of each type of inquiry from low-level structured inquiry to high-level open inquiry.

The Inquiry Continuum

Teachers sometimes believe that in order for students to be engaged in inquiry-oriented activities they need to be designing scientific investigations from scratch and carrying them out on their own. This simply isn't true. Elementary students cannot be expected to immediately be able to design and carry out their own investigations. In fact, most students, regardless of age, need extensive practice to develop their inquiry abilities and understandings to a point where they can conduct their own investigation from start to finish. Luckily, there are many levels of inquiry that students can progress through as they move toward deeper scientific thinking.

We've found a four-level continuum—confirmation, structured, guided, open—to be useful in classifying the levels of inquiry in an activity (Figure 1). The continuum focuses on how much information (e.g., guiding question, procedure, and expected results) is provided to students and how much guidance you will provide as the teacher (Bell, Smetana, and Binns 2005; Herron 1971; Schwab 1962).

At the first level, *confirmation inquiry*, students are provided with the question and procedure (method), and the results are known in advance. Confirmation inquiry is useful when a teacher's goal is to reinforce a previously introduced idea; to introduce students to the experience of conducting investigations; or to have students practice a specific inquiry skill, such as collecting and recording data. For example, you may want students to confirm that the less air resistance an object has the quicker it will fall. Students can create paper helicopters with wings of different lengths to confirm this idea. They follow the directions for doing the experiment, record their data, and analyze their results.

At the next level, *structured inquiry*, the question and procedure are still provided by the teacher; however, students generate an explanation supported by the evidence they have collected. Using the same paper airplane example, students would not be told the relationship they were investigating ahead of time. They would need to use the data collected showing that airplanes with longer wings took longer to fall to understand that the longer wings created greater air resistance and slowed down the airplanes. While confirmation and structured inquiry are considered lower-level inquiries, they are very common in elementary science curricula. These kinds of inquiries are important because they enable students to gradually develop their abilities to conduct more open-ended inquiry.

At the third level, *guided inquiry,* the teacher provides students with only the research question, and students design the procedure (method) to test their question and the resulting explanations. Because this kind of inquiry is more involved than structured inquiry, it is most successful when students have had numerous opportunities to learn and practice different ways to plan experiments and record data.

Just because students are designing their own procedures does not mean that the teacher's role is passive. To the contrary, students need guidance as to whether their investigation plans make sense.

At the fourth and highest level of inquiry, open inquiry, students have the purest opportunities to act like scientists, deriving questions, designing and carrying out investigations, and communicating their results. This level requires the most scientific reasoning and greatest cognitive demand from students. With ample experience at the first three levels of inquiry, students at the fourth- and fifth-grade levels will be able to successfully conduct open inquiries. It is only appropriate to have students conducting open inquiries when they have demonstrated that they can successfully design and carry out investigations when provided with the question. This includes being able to record and analyze data, as well as draw conclusions from the evidence they have collected.

Students can experience multiple levels of inquiry during a single unit with related scientific concepts. Here we share examples of the various levels of inquiry—from structured to open—as it occurred during a recent fifth-grade unit on sinking and floating.

Structured Inquiry: Dancing Raisins

To begin, I pour about 500 mL club soda into a clear plastic cup filled with four or five raisins. I walk around the classroom with the cup and ask students to note anything that happens in the cup and to record their observations in their science journals. Students are usually chattering about the raisins moving up and down, so the natural question arises, "Why are the raisins bobbing up and down in the soda?"

Next, students explore this question through a structured inquiry. Provide each small group of students with two clear cups and a small box of raisins. The students start by filling up one cup with 500 mL water and dropping in four or five raisins. They draw the setup in their science notebooks and write detailed observations. Students generally observe the raisins sink to the bottom, and some do see a couple bubbles attached to the side of some raisins. Next, students repeat the procedure with soda and raisins in the other cup.

I ask students to share their written observations and any explanations they may have for what was making the raisins "swim" around the glass. Students are quick to tell me that the "bubbles" help the raisins rise to the surface. When I ask them why the bubbles went up to the surface, a student says they are lighter than the water. I ask her what she means by that and she says they are "less dense." She can't explain what that means, but we are on the right track and I write the word *density* on the board.

Next, I ask students to think about how the raisin has changed in order to float up to the surface. With their partners, students discuss their observations and consider what property of the raisin changed in the soda. Initially, students may talk about how the raisin has gotten lighter because air bubbles have been added. As a group, we first identify some properties of the raisin, such as mass and volume. Then, students are on their own to devise an explanation in their

Figure 1.

The four levels of inquiry and the information given to the student in each one.

Inquiry Level	Question	Procedure	Solution
1—Confirmation Inquiry *Students confirm a principle through an activity when the results are known in advance.*	✔	✔	✔
2—Structured Inquiry *Students investigate a teacher-presented question through a prescribed procedure.*	✔	✔	
3—Guided Inquiry *Students investigate a teacher-presented question using student designed/selected procedures.*	✔		
4—Open Inquiry *Students investigate questions that are student formulated through student designed/selected procedures.*			

journals considering how the mass or volume of the raisin changes based on their observations. Students start to recognize that the mass of the raisin couldn't have gone down since the entire raisin is still present. They then observe that the volume of the raisin with the bubbles attached has gone up, because the bubbles are taking up space, even when that space is filled with air. At this point, it is not imperative that every student has the correct "answer" in their journals. The journals reflect the evolution of their thinking and they are encouraged to add new understandings to their journal as we proceed through the unit. Students articulate in their journal entries that the bubbles add volume to the raisin system, making it less dense and causing the raisin to float to the surface. We share some of their journal entries and move onto the next inquiry. At this point, students have a grasp on the idea that objects that are less dense than the liquid they are in will float, and those that are more dense will sink. They also have an evolving understanding of how density is affected by the properties of mass and volume. With these ideas as a foundation and developing inquiry skills, students are ready to transition to a guided inquiry that will further explore the same concepts. By providing students with the question and procedure of this structured inquiry, they were able to explore the specific concepts that I intended in a student-centered, investigative manner.

Guided Inquiry: Soda Can Float

To develop deeper understandings of sinking and floating experiences, fill a clear glass aquarium with water and display one can of regular soda and another can of diet soda. Ask students to predict in their science journals how the cans will behave when placed in the tank of water and why. They share their written predictions and then I ask for student volunteers to place each can in the water. Students are generally shocked by the results, as the regular soda can sinks to the bottom, and the diet soda can bobs at the top. The natural question that arises from this phenomenon is, "Why does the regular soda sink and the diet soda float?"

In groups, students brainstorm ways to figure this out. They record a plan in their journals for how to accomplish this and share with the class. One group proposes that we empty out the contents of the two cans and compare how much liquid is inside. Another group points out we can just look at the side of the can to see what information we can find before we empty it. I hand over the cans to two students, and they search for relevant information; they discover that the volume of the two cans is the same. Another group asks if they can take the cans back to the scales and find the mass. They quickly discover that the mass of the regular soda is greater than the mass of the diet soda, and then go on to explore what ingredients lead to a greater mass by reading the labels on the cans.

In their journals they describe the relationship between mass and density, explaining that as the mass goes up, the density goes up. They deduce this since they know that higher density objects are more likely to sink combined with the observational evidence that the two cans had the same volume and the regular soda had a greater mass than the diet soda. While this may be an appropriate time to introduce the formula for density, I chose not to based on the age level and the instructional goals. It was more important to me that they understand the relationships between mass, volume, and density based on their experiences than to remember a formula. As they are writing in their journals, a student calls out, "What would happen if we add salt to the water in the aquarium?" This leads to another guided inquiry. The following student explanation demonstrates the level of reasoning that results from inquiry:

"When we added salt, the regular soda slowly rose to just the top of the water! I think that since the soda was denser than the diet soda and the diet soda rose to the top and the regular soda sank (in the water), that must mean that it is denser than the water. But when salt was added, it made the water denser than the regular soda, so it rose to the top, just like the diet soda. Why did this happen? Well, the mass of the water got heavier when the salt was added, and when something is less dense than the water, it rises to the surface."

In this case, the guided inquiry was facilitated whole class with one experimental setup. While each student didn't individually get to manipulate the variables, the direction of the investigation, including the procedure and data analysis, were directed by the students collectively.

Open Inquiry: Sinking and Floating

During the previous explorations, students made connections about mass, volume, and density. They developed the understanding that increasing mass makes an object more dense and that increasing the volume makes an object less dense when submerged in a liquid. The saltwater exploration also solidified the idea that how dense an object is in a liquid is very dependent on the density of that liquid. Once they are comfortable with these ideas, they are ready to pursue their own questions about sinking and floating. In order to familiarize students with the materials available and spark their curiosity, set up clear plastic tubs filled with water. At each station, place a collection of items, some of which will float and others that will sink. (I include a banana, apple, orange, cork, penny, bobber, various cylinders with the same volume but different masses, a piece of wood, and a ball of clay. I also include some ironwood, which looks like an unsuspecting piece of wood but immediately sinks in water (see Internet Resources). Students record all of these items in their science notebooks and make predictions as to whether they will float or sink. After confirming or disconfirming their predictions, students each write five "I wonder" questions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Students explore items that sink or float.

that were sparked by their explorations. The following questions are examples of what students have pursued:

- I wonder how dense the water is?
- I wonder what will happen if you put in something that is the same density as water?
- I wonder which is less dense, the apple or the orange?
- I wonder why does the light wood float and the dark wood sink?
- I wonder will an orange still float if you remove its peel?

I ask students to reflect on which question they think will be both most interesting to investigate and also feasible based on the resources available. In order for students to carry out their investigations, they need to include their focus question, a prediction, a detailed plan for how they will carry out their investigation, and the data table (if necessary) they are going to use. For younger students, this can be very tedious, so I often let them draw a diagram for their plan and don't require that everything be written in complete sentences. Once they have all of their planning done, they have to get approval before starting their investigations.

Students are not only able to carry out these open inquiry investigations, but do so efficiently and enthusiastically. Their explanations reflect logical reasoning and are supported by the evidence they have collected. While students do reach stumbling blocks in their investigation designs and data collection procedures, they work through these impasses, all the time learning about the nature of scientific inquiry and how to problem solve.

Assessing Progress

The science notebooks provide the primary means of evaluating whether students achieve scientific understandings of the relevant science content. After each investigation, I looked through student notebooks to check their understanding of concepts as well as whether the descriptions of their experimental designs were appropriate for the research questions they were asking. I often asked them to answer additional questions to clarify their ideas and made comments on the direction their thinking was going. When students receive their journals back from me, they are always given a couple minutes to look over my comments, make appropriate revisions, and answer questions I posed. As a result, there is an ongoing scientific dialogue occurring over the course of the unit.

As students experience the multiple levels of inquiry, they will develop the abilities and understandings of scientific inquiry. Students need to experience science through direct experience, consistently practicing the inquiry skills and seeking deeper understanding of science content through their investigations. Accomplishing these goals is feasible once you can identify the level of inquiry in science curriculum materials, and revise them as needed to provide students with a range of complexity in their inquiry experiences. ■

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Internet Resource

Educational Innovations
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Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996).

Content Standards

Grades 5–8

Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Standard B: Physical Science

- Properties and changes of properties in matter

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academy Press.