FIRE UP the *Inquiry*

Lose the routine, tweak your "cookbook lab," and reach a level of open inquiry with these strategies used during a unit on heat.

By Kimberly Lott

Does the level of inquiry in your classroom need a boost? Highly structured "cookbook labs" are common in elementary classrooms because they are driven by step-by-step procedures. They are easy for teachers to set up and easy for to students to perform. However, they require minimal intellectual involvement for either the teacher or the student (see Internet Resource). With cookbook labs, students are not learning basic inquiry skills they will need to advance to more guided and open inquiry on their own; therefore, teachers get stuck in a lower-level inquiry routine. By following the basic steps outlined here, teachers can create activities to engage their students in higher forms of inquiry. To illustrate how a typical cookbook lab can be shifted to structured, then guided, and finally to open inquiry, I will describe a simple investigation third graders did on how insulators are used to reduce heat transfer. The heat activities I used were adapted from the heat unit found in *Science in Elementary Education: Methods, Concepts and Inquiries* (Peters and Stout 2011).

Scientific inquiry *can* occur on varying levels (Figure 1, p. 30), but to reach the level of open inquiry, students must be able to master certain scientific process skills, including: formulating questions, planning investigations, using tools and techniques of data collecting, and making evidence-based conclusions (NRC 1996). Every advance in inquiry levels allows students to develop and master more of these skills.

How do teachers break out of the cookbook routine? The obvious answer is to do more guided and open inquiry activities. To many teachers this sounds like an impossible task because they have the misconception that this would involve creating all new activities—but that is simply not true! The process of moving to full inquiry often requires only subtle changes to the existing cookbook labs teachers are currently using. Obviously, not all labs are appropriate for full inquiry, but most can be shifted to at least structured inquiry, and many can be shifted to open inquiry.

Figure 1.

Levels of inquiry.

Inquiry Level	Question	Procedure	Solution
Confirmation Inquiry: Students are confirming previously learned material.	✓	✓	✓
Structured Inquiry: Students are given the question and procedures, but make their own conclusions based on their collected data.	✓	✓	
Guided Inquiry: Students are given the question, but they plan the investigation, collect and organize their own data, and make evidence-based conclusions.	✓		
Open Inquiry: Students generate their own questions, plan their investigation, collect and organize their data, and make evidence-based conclusions.			

ADAPTED FROM BANCHI AND BELL (2008)
Note: See Figure 1 in the Guest Editorial on p. 9.

Step 1: From Confirmatory to Structured Inquiry

Confirmatory inquiry activities are the typical "cookbook labs." Students are simply confirming what they already know. The teacher has usually introduced a topic and given the students background information on the objective of the activity. Next, the students are given a question for investigation and the procedures to follow to answer the question. Because the students have been given background information, they already know the correct outcome of the investigation. In a structured inquiry activity, students are given the question and procedures, but the solution is still a mystery to them. Shifting from confirmatory to structured inquiry allows students to practice the science process skill of using the tools and techniques of collecting data to form evidence-based conclusions. This step toward full inquiry is easiest for teachers to make because it requires the fewest changes to an existing activity. First, change the title of the activity to a question (if it is not already). Because the students did not generate the question, it needs to be engaging to spark their curiosity. Next, remove any objectives from student handouts that would clue the students to the "answer." In addition, make sure questions for students are unbiased and require them to make conclusions based solely on their collected data (Sherwood and Zavorol 2007). Some additional tips include modifying questions so that they (a) require students to make general summary statements from their data instead of specific objective answers and (b) lead students to ultimately discover the intended learning objective.

The final and most crucial step toward structured inquiry is to perform the investigation *before* instruction or text reading. Start the inquiry with an engaging book or demonstration to introduce the topic, but then let the students explore the concept through the investigation. After the exploration, teachers can then introduce the

Figure 2.

Confirmatory inquiry activity.

Keep in the Heat

Background Information:
Most houses have an inside and outside wall. Packed between the double walls of many houses is insulation. Insulators are used to reduce heat transfers; therefore, keeping the heat inside.

Objective:
Students will be able to explain that insulators are better at keeping temperatures constant (either hot or cold) because less heat is transferred.

Materials:
2 baby food jars, hot water, two airtight plastic containers, quilt batting, thermometers

Procedures:
1. Take two small baby food jars and fill them with hot water. Place the lid on each jar.
2. Wrap one jar with quilt batting. Place in the container and cap it. Place the other jar in another container and cap it.
3. After 20 minutes, remove the jars from the containers. Open the lids. Use a thermometer to take the temperature of each jar of water.

Data Table:

Jar	Temperature
Jar without insulation	
Jar with insulation	

Questions for Discussion:
Which jar of water felt warmer after 20 minutes?
Explain why the jar with insulation was warmer.

Figure 3.

Structured inquiry activity.

Why do we have insulation in our houses?

Materials:

2 baby food jars, hot water, two airtight plastic containers, quilt batting, thermometers

Procedures:

1. Take two small baby food jars and fill them with hot water. Place the lid on each jar.
2. Wrap one jar with quilt batting. Place in the container and cap it. Place the other jar in another container and cap it.
3. After 20 minutes, remove the jars from the containers. Open the lids. Use a thermometer to take the temperature of each jar of water.

Data Table:

Jar	Temperature
Jar without insulation	
Jar with insulation	

Question for Discussion

Were there any differences in the temperatures after 20 minutes? What do you think is happening?

specifics about the concept (i.e., scientific explanations for results and vocabulary).

Why Do We Have Insulation in Our Houses?

I started with a typical confirmatory investigation of heat and insulators in which background information is given to students, so they simply confirm the information with the investigation (Figure 2). With a few subtle changes, the heat and insulator activity was easily transformed into a structured inquiry lesson (Figure 3). The activity title was changed into a more engaging open-ended question that would not lead students toward the "right" answer. The objective was removed from the activity. The questions provided after the activity led the students to confirm the previously learned concept that insulators reduce heat transfer, so they were replaced by a single question that allows students to make possible conclusions based on their data. Using the modified activity, the students can investigate the effects of insulation on the temperature of water and discover for themselves that insulators reduce heat transfer.

Step 2: From Structured to Guided Inquiry

Guided inquiry occurs when students practice not only collecting data to make evidence-based conclusions but also plan the investigation. The shift from structured to guided inquiry is not as easy as moving from confirmatory to structured inquiry because not every activity is appropriate for this shift. The questions a teacher needs to ask when considering this shift are:

- Do students have the background knowledge to develop the procedures to investigate this question?
- Are there multiple methods of investigating this question?

If the answer to either of these questions was "no," then guided inquiry is not an option for this investigation; however, these types of inquiries can be made less structured. The teacher can demonstrate the procedures, but allow the students to plan the data collection and organization. Remove any data tables or graphs from the student handouts to allow students to make decisions about how data should be organized and to choose the most appropriate graph for their data (Sherwood and Zavoral 2011).

If the answers to these questions were "yes," then guided inquiry is an option for this investigation. The teacher can simply remove the procedures, data tables, and graphs from the student handouts. Give the student the question and offer a list of possible materials. Guide the students to think about which variables are relevant and how they can measure them (Sherwood and Zavoral 2011).

Allow students time in class to develop their procedures. As they are working, monitor their progress and offer guidance. Ask questions to spark ideas and reduce frustration levels. Some example questions might be:

- What are you doing?
- What are you thinking?
- What do you think would happen if. . .?

When students answer a question, the teacher must be objective as to not lead them toward the "right" answer (Sherwood and Zavoral 2011). Even though students will be developing their own procedures, their procedures must still fit within classroom safety parameters (Sherwood and Zavoral 2011). Teachers need to discuss safety concerns with their students while they are making their investigation plans and make sure to "sign-off" on their procedures before they begin. Students need to understand that just because their investigation passed the safety approval does not mean that it is the correct way to solve the problem (Sherwood and Zavoral 2011).

CAUTION

Which Material Makes the Best Insulator to Keep Heat in?

Because I wanted to have my students do a more guided inquiry, I set up the structured activity before school (Figure 3). Using that activity as engagement, I

Figure 4.

Guided inquiry activity.

Which material makes the best insulator to keep heat in?

How will you know which is the best insulator?

What materials will you need?

What steps will you take to investigate different insulators?

Question for Discussion

Which materials were the best insulators? Why?

then challenged the students to see whether we could determine which material makes the best insulator. My students were now performing guided inquiry (Figure 4). Instead of simply investigating the effect of insulators, students were now highly engaged in a competition to find the "best" insulator. Working in cooperative learning groups, students listed the materials they might need. I had several different insulators on hand (cotton, wool, sawdust, torn paper, hay) but I encouraged the students to think of other materials that might be used. Students then planned their procedures to test their material. Many of the student groups used the same procedures as I had demonstrated in the structured inquiry activity. However, other groups felt that a thicker layer of insulating material was needed, so they changed the container that held the insulating material to accommodate more insulation. Because hot water from the tap will be used for this experiment, I advised my students on the proper procedure for obtaining the hot water (out of the hot water tap), carefully transporting it back to their desk (with a Styrofoam cup), and then making sure it was immediately placed in a sealed container to reduce the risk of spilling and accidental scalding of group members. After they were cleared for safety, students tested their material and class results were shared to determine which group had the "best" insulator. A class discussion followed about why certain materials (or combinations of materials) were better insulators.

Step 3: From Guided to Open Inquiry

To have open inquiry, students must be able to generate their own testable questions. Many times student questions come from observations they make during structured or guided investigations. Observation skills are found at all levels of inquiry, but they are especially crucial for open inquiry. Even if they have participated in lower levels of inquiry, students may need to practice their observation skills before beginning an open inquiry investigation (Anderson, Martin, and Faszewski 2006).

Along with observation skills, students often need teacher modeling on how to turn their observations into questions. A strategy called "think-aloud" can help students make the transition between their abstract observations to testable questions (Martin-Hansen and Johnson 2006). Teachers talk aloud with their students as they make observations and discuss questions that emerge. By modeling this behavior for the students, they will be able to start generating their own questions from their observations.

Once students start to generate questions, they must be able to distinguish which questions are appropriate for inquiry investigations (Martin-Hansen and Johnson 2006). Sometimes questions that arise can be answered by making careful observations. For example, a student might ask, "Do certain butterflies have a favorite flower?" This type of question would have to be answered by careful observation because creating a butterfly garden in the classroom is not a feasible option. If a student asks, "What poisonous snakes live in our area?" The answer to this question can be found through books or internet resources.

Another technique for helping students develop questions for investigation is the "Four Question Strategy" (see Internet Resource). This strategy can be used during a whole-class discussion or could be used with smaller student groups. The teacher starts by asking the students the first question, "What materials are available for studying _____?" (Fill in the blank with the topic of interest.) Students then make a list of everything they might need. The teacher then asks the second question, "How do (does) ____ act?" The students make a list of observable changes in the object/organism/material being studied. The teacher then asks the third question "How could you change the materials to affect the action?" The students review the list of materials from question 1 and list ways they could change them. Last, the teacher asks the fourth question, "How can you measure or describe the response of ____ to the change?" Students review their list of actions from question 2 and list possible methods of recording the actions.

After working through the four questions, students are then ready to form a question for investigation by simply stating "What would happen to ____ (insert action from list 2) if I were to change _____ (insert material from list 1)?" From their list from question 3, they can identify the material they will change (independent variables) and all the other materials that have to stay the same (controlling variables). Their list from question 4 will help them identify the response to the change (dependent variable) and the most accurate methods of data collection to record the change.

Many times open inquiry questions emerge from guided or structured inquiry activities. The question a teacher should ask when considering whether an activity is appropriate for this shift is, "Can this activity be extended to another area of student interest?" If the answer is "yes," then open inquiry is a logical, easy step for students to make.

During our discussion about the best insulators, a student asked, "Are insulators good at keeping heat out? What if we had started with ice water?" And just like that, we were about to embark on open inquiry! Students used the same procedures they developed for the guided inquiry activity, but this time they were investigating their own question about insulators.

Subtle Shifts, Deeper Engagement

Advancing the levels of inquiry from confirmatory and structured inquiry to more guided and open inquiry should be a slow and deliberate process to alleviate stress on both the students and the teacher. With every step, students are given more control of the scientific process. Most students are not prepared initially to take on this control. This can be an especially frustrating endeavor for students that have grown accustomed to being told what to do (i.e., through cookbook labs). Students must have time to practice their inquiry skills at lower levels of inquiry before moving up to the higher levels. To determine when the students are ready to move up the inquiry level, I developed a set of criteria for assessing inquiry skills (see NSTA Connection for a complete list). The assessment is designed for individual students but could also be used for small student groups or a whole class if appropriate.

Just as students need more practice taking on more control of the scientific process, teachers need practice at giving up that control. When students start to design their own procedures, teachers need practice guiding students through this process and avoiding the tendency to just tell them what to do. Teaching higher levels of inquiry requires additional research and planning because this is an exercise that requires a deeper intellectual engagement into the topic and not just a superficial understanding to explain the step-by-step procedures. However, just like the students, the teachers practice these skills at lower levels before moving up to the next level. Learning to make those subtle shifts from cookbook to full inquiry provides a mechanism for teachers to slowly wade into the pool of full inquiry instead of feeling they have to jump in to either sink or swim. ■

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Internet Resources

Contrasting Cookbook with Inquiry-Based Labs
www.phy.ilstu.edu/pte/312content/inquiry_vs_cookbook_lab.pdf

NSTA Connection

Download the complete set of steps for assessing inquiry skills at *www.nsta.org/SC1103.*

Connections to the Standards

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

Content Standards

Grades K–4

Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry

Standard B: Physical Science
- Light, heat, electricity and magnetism
- Transfer of energy

Teaching Standards

Standard A:
Teachers of science plan an inquiry-based science program for their students.

Standard B:
Teachers of science guide and facilitate learning.

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