Science activities can take many forms, ranging from highly structured procedures through which students move toward known outcomes, to free explorations with unanticipated results. However, many of the labs our students participate in only help to explain scientific phenomena and do little to promote student curiosity. They are not student centered and do not require higher-level thinking. Is it any wonder why these perfunctory exercises have become known as “cookbook labs”? Simply follow the recipe and you will get the expected results. Cookbook labs have been a part of science programs for years, even though they serve little purpose other than to verify phenomena that have been previously presented by means other than through investigations.

The new Framework for K–12 Science Education proposes, “The actual doing of science or engineering can also pique students’ curiosity, capture their interest, and motivate their continued study” (NRC 2012, p. 42). However, many people, including some teachers and curriculum designers, believe that any form of hands-on activity is analogous to inquiry. Llewellyn (2002) asserts that providing students with hands-on opportunities does not necessarily mean they are doing inquiry. In fact, Minner, Levy, and Century (2009) describe a study that directly compared two hands-on curricula to determine whether it was the hands-on component or the inquiry principles that made a difference in student learning. They concluded that hands-on activities alone were not sufficient for conceptual change and students needed time to process...
and reflect. In addition to the hands-on component associated with lab work, inquiry-oriented investigations involve a great deal of student inquisitiveness. We submit that curiosity is a personal construct that, according to Metz (1975), is generally stimulated by some unique feature or discrepancy in the materials or challenge presented. Additionally, the manner in which a teacher introduces a lesson is critical to piquing student interest. Crafting an appropriate focus question, such as “If you double the number of magnets, what do you think will happen to the strength of the system?,” or asking students to work together as a group to design a way to increase the flight distance of a toy airplane is much more impactful than simply stating, “Today we will be...”

Cookbook science activities follow a linear path to a known outcome, telling students what procedures to follow, which materials to use, what data to record, how to record them, and what questions to answer along the way and when they are done. The American Association for the Advancement of Science (1993) maintains that there is more to inquiry than adhering to a sequential set of procedures.

There are many ways to actually “do science.” Is it possible, then, to convert teacher-directed, highly structured lessons to more open-ended inquiry experiences that allow for student input, wonder, and individual exploration? After all, chefs do not always use cookbooks—why should students?

What is inquiry?

“Attempts to develop the idea that science should be taught through a process of inquiry have been hampered by a lack of a commonly accepted definition of its component elements” (NRC 2012, p. 43). Therefore, any discussion that involves inquiry should provide an operational definition of the term, for without some consensus as to its meaning, teachers cannot possibly cultivate it in the classroom. According to the National Research Council (1996) in its National Science Education Standards:

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

Considerations

Before we address how to convert cookbook activities to inquiry investigations, we must attend to a few cautionary notes. Initially, consider the practicality of altering a lesson in the first place. Not all activities and investigations lend themselves to inquiry, nor should they. Some laboratory activities are designed for students to make observations, gather data, verify phenomena, and set the stage for more student-centered, inquiry-based explorations that might follow. Second, lessons in which student safety might be a concern, or in which limited materials would prohibit direct student involvement, might best be relegated to the status of a demonstration. A third consideration for teachers is whether the content piece of the activity is developmentally appropriate for their students and whether it fits into their standards-based curriculum. If a cookbook lab is deemed safe, developmentally appropriate, and directly related to curricula, and if sufficient materials are available, it may be a candidate for conversion.

Subtle shifts for folding in inquiry

The following suggestions are simple solutions for folding inquiry into a cookbook lab. These ideas may be used individually or in combination with one another to adapt current lab activities to meet the needs of the teacher. Additionally, Figure 1 represents an example of this folding.

Rearrange the lesson

Increasing the inquiry level of a lesson can be accomplished simply by rearranging the order of the lesson components. The background information, although an important content piece, is often best used after the lab and referenced during subsequent communications. According to Lowery (1998), if readers have little background related to the content of what they are reading, they will gain little from the experience. Because reading has such power when it follows experience, the National Science Foundation–sponsored science programs provide reading materials for use after students have gained some experience through manipulation of materials.
### FIGURE 1

Inquiry continuum for shifting from cookbook labs

<table>
<thead>
<tr>
<th>Level of inquiry</th>
<th>Prelaboratory experience</th>
<th>Laboratory experience</th>
<th>Postlaboratory experience</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Problem or issue to be explored</td>
<td>Carries out the procedure</td>
<td>Supplies answers or conclusions</td>
</tr>
<tr>
<td>0</td>
<td>Teacher</td>
<td>Teacher</td>
<td>Teacher</td>
</tr>
<tr>
<td>Teacher is responsible for all activities.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Teacher</td>
<td>Teacher</td>
<td>Teacher</td>
</tr>
<tr>
<td>Teacher demonstrates. Students must research applications.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Teacher</td>
<td>Teacher</td>
<td>Teacher</td>
</tr>
<tr>
<td>Teacher demonstrates. Students supply their own answers, conclusions, and applications.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Teacher</td>
<td>Teacher</td>
<td>Students</td>
</tr>
<tr>
<td>Teacher initiates activity and provides procedure. Students conduct investigation and follow up.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Teacher/Students</td>
<td>Students</td>
<td>Students</td>
</tr>
<tr>
<td>Desired level of inquiry. Teacher poses problem. Students are responsible for all other activities.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Students</td>
<td>Students</td>
<td>Students</td>
</tr>
<tr>
<td>Total student involvement; no restriction on topics or methods.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Adapted from Priestly et al. 1998.*
Of primary consideration is the activity section of the lab itself and its focus on student learning, for this is the foundation on which the remainder of the lesson is built. In other words, do the activity first. Reading, vocabulary development, writing, discussions, editing, research, and so on should follow and complement the activity or investigation. This suggested procedure may not be appropriate in all cases, and providing a variety of learning strategies will help differentiate your overall approach.

**Go unscripted**

Perhaps the heart of the matter is the extremely scripted nature of cookbook labs. In an inquiry lab, the teacher provides the question to be studied, but students are responsible for developing procedures, data tables, and evidence-based conclusions. One first needs to examine the cookbook lesson under consideration and determine how the responsibility of lesson components can be shifted to students, thus increasing the level of inquiry. Even small modifications in the design of an activity can have dramatically positive effects on student learning. Simple adjustments—such as asking students to perform a demonstration, taking suggestions from students regarding subsequent procedures, or even asking questions about what students are thinking and experiencing—can contribute to folding inquiry into the activity. Can some of the recipe be eliminated or selectively altered to allow for decision making on the part of students? Could the responsibility for selecting and gathering materials be given to students? Could students create the procedure, collect data, or even craft a data display? Could low-level knowledge questions be transformed into higher-level synthesis and application questions? Could students apply their findings in appropriate extension investigations or suggest alternative solutions themselves?

**Develop focus questions**

Another simple shift in a traditional cookbook lab is to modify any statements or titles that tell students what to expect. For example, descriptive lab titles such as “Cleaning Up Spilled Oil,” “Identifying Physical Properties of Matter,” or “Mineral Identification” leave little to the imagination. Using focus questions, however, shifts the activities toward being more student centered. According to Malone (2009), the use of well-crafted focus questions amplifies and communicates lesson objectives and helps stimulate student curiosity and a need to find answers. Converting the preceding descriptive lesson titles to focus questions might take the following form: “How could you clean up an oil spill?”; “What are some ways to classify matter?”; or “How do geologists identify minerals?”

**Write for reflection and understanding**

Writing can also be a very powerful tool for student reflection and can serve as both formative and summative assessments for determining how students are processing information. In fact, the *Frameworks for K–12 Science Education* assert the following:

Students should write accounts of their work, using journals to record observations, thoughts, ideas, and models. They should be encouraged to create diagrams, and to represent data and observations with plots and tables, as well as written texts, in these journals. They should also begin to produce reports or posters that present their work to others. (NRC 2012, p. 92)

Reflective writing can be inserted within the body of a laboratory at an appropriate break point and definitely at the conclusion to help determine how students are processing the information. Keeping in mind that inquiry shifts some of the responsibility for learning from the teacher to students, what students write is an outward expression of what and how they are thinking. This writing should be reflective so that it provides an opportunity for students to revisit the information acquired in the lesson. The more encounters students have with information, the more likely they will develop a deeper understanding, especially if these encounters vary in some way. An assortment of writing prompts, as offered by Shaw and Reid (2007), can provide a glimpse into what students are thinking and where misconceptions or confusion may still exist (Figure 2).

**Vary questioning techniques**

A written lesson plan will only take the teacher so far. Student communication in the form of planning and sharing sessions, reporting, writing, and editing, for example, are absolutely essential for inquiry. As previously mentioned, research indicates that students need time to process for meaning. They need time to discuss and reflect. Therefore, teachers should provide opportunities for discussion and reflection. Even the traditional teacher demonstration can be easily enhanced through appropriate teacher questioning and response strategies (see Gooding and Metz 2008).
Just because students are not physically involved does not mean they cannot be mentally engaged to make sense and meaning of the experience. Involving students through the use of open-ended queries about the presentation, asking them for their observations and interpretations of what is happening and why, and seeking directions from students for further exploration can provide opportunities for discussion and reflection. These techniques can even subtly shift a demonstration from being teacher centered to being more student centered.

**A cookbook conversion**

Let us examine how this shift to inquiry might work with a common cookbook lab, Water Changes Our Earth, which introduces the erosive effects of water.

**Prelaboratory experience**

In the original lesson, the teacher introduced the activity by telling students what they were about to do. Then students read about the effects of water on the Earth’s surface. We suggest the teacher stimulate students’ curiosity by rephrasing the lab title as a focus question and using it as an engagement. For example, using the introductory phrase “Today we will be looking at the erosive effects of water on Earth materials” or relying on the lab title “Water Changes Our Earth” elicits little or no curiosity from students. Focus questions that convert the title might read, “How do you think water can change the surface of the Earth?” or “What do you think occurs when large amounts of water flow over Earth materials?” These questions serve to stimulate interest and communicate the lesson objectives.

Additionally, the background reading was also part of the prelab of the original lesson. We are suggesting a major change in the placement of this reading. Although this background information is an important content piece, it is best used after the lab and subsequent discussions. Olson (2008) agrees, asserting that the learning sequence should proceed from the concrete to the representational to the symbolic. Because reading exemplifies the last, it should come after the activity. “Scientists do not begin with vocabulary words and try to figure out how to apply them. ... They begin with a puzzling phenomenon that they attempt to explain” (Olson 2008, p. 52). We submit that if scientists learn that way, students of science should also learn that way.

**Laboratory experience**

The procedure and its completion might remain as per the original lab, provided it is an introductory experience. Conversely, if the lab is an extension of a previous activity, we suggest that student groups craft all or part of their own procedures, as this will force

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**FIGURE 2** Sample writing prompts for subtle shifts

- At first I thought, but now I know ____________________________.
- One thing I will remember from today’s lesson is ____________________________.
- I am still confused about ____________________________.
- The big ideas I gained from the investigation were ____________________________.
- Next I would like to explore ____________________________ because I wonder ____________________________.
- One thing that I still need help with is ____________________________.
- I am still uncertain about ____________________________.
- When I started this investigation, I knew ____________________________, and now I have also learned ____________________________.
- I still wonder ____________________________.
- These results make me think ____________________________ will happen because ____________________________.

(Shaw and Reid 2007)
them to revisit the initial experience and take a role in the decision-making process. The transference of responsibility to students can also apply to the selection and distribution of materials, the types of data that might be collected, and the manner in which the data are displayed.

Before launching into the postlaboratory experience, we suggest a class discussion so that students can openly share their observations, data, and inferences about what occurred. This is also an opportune time for the teacher to introduce vocabulary words associated with this activity and assign the background reading. Students are now better prepared to handle this symbolic component because they have had the hands-on experience, discussed what they observed, compared data, and been introduced to the vocabulary terms they will encounter in the reading.

**Postlaboratory experience**

The postlaboratory experiences fall into two categories: answers or conclusions and further explorations. Increasing the conceptual level of perfunctory cookbook labs requires a bit of rewriting, with an eye toward the higher-order thinking skills of analysis and synthesis. For example, a question such as “What happened to the different sand particles when the water ran through them?” could be changed to “Why do you think different sand particles were not distributed evenly?”

The outcome of a lab could be used to drive further investigation. The focus for a lab extension is generally based on questions posed by students or challenges issued by the teacher. Examples include the following: “What do you think would happen to the landforms if we used more water?”; “How do you think the river valley would look if large rocks were present?”; “What effect do you think the slope or angle of the trough has on the creation of landforms?”; and “What factors create the greatest and least amounts of erosion?”

**Conclusion**

The benefits of inquiry in the classroom are well documented. The examples provided herein are just a few of the many subtle, yet simple, lesson transformations that can be used to fold inquiry into a cookbook lesson. These suggestions are easy and efficient, and they allow for increased inquiry with minimal effort and little time. Although there may not be a specific formula for cookbook revisions, we have found success with the strategies previously described. So we encourage you to shift your cookbook recipes subtly and to serve students from a new menu of more satisfying and stimulating educational experiences.

**References**


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