SIMPLIFYING *Inquiry* INSTRUCTION

Assessing the inquiry level of classroom activities

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Inquiry instruction is a hallmark of the current science education reform efforts. Science teachers know that inquiry is important, yet most teachers lack a practical framework of inquiry to inform their instruction.

Defining inquiry and assessing how much inquiry is supported by a particular activity or lab can be difficult and confusing. This article presents a simplified explanation of inquiry and provides a rubric that will enable science teachers to determine whether an activity is inquiry based and, if so, to assess the level of inquiry it supports. Additionally, the framework presented will allow teachers to easily adjust the level of inquiry in an activity and increase the amount of inquiry in their science instruction.

What is inquiry?

The *National Science Education Standards* characterize inquiry instruction as involving students in a form of active learning that emphasizes questioning, data analysis, and critical thinking.

> Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments (NRC 1996, p. 105).

At its heart, inquiry is an active learning process in which students answer research questions through data analysis. One might argue that the most authentic inquiry activities are those in which students answer their own questions through analyzing data they collect independently. However, an activity can still be inquiry based when the questions and data are provided, as long as students are conducting the analysis and drawing their own conclusions. Furthermore, most students need substantial scaffolding before they are ready to develop scientific questions and design effective data collection procedures to answer these questions. The ideal plan for inquiry instruction recognizes this fact and seeks to help students progress to greater inquiry skills through a series of graduated steps, as described later in this article.

Inquiry or not?

The first question to ask when determining whether an activity is inquiry based is, "Are students answering a research question through data analysis?" Many worthwhile hands-on activities traditionally performed in science classrooms do not involve a research question or data analysis. For example, constructing models of cells or atoms, assembling a wildflower collection, or constructing a scale model of the solar system can all be excellent activities. However, as traditionally taught, these activities do not involve research questions and therefore do not qualify as inquiry activities.

For the same reason, activities designed to give practice with a particular skill, such as learning to use a triple beam balance or reading a graduated cylinder, do not constitute inquiry. Inquiry-based activities must start with a scientific question. For example

- How does the amount of a substance affect its density?
- How does temperature affect the rate of a chemical reaction?
- Did the latest El Niño impact the climate where I live?
- In what ways does the Moon's shape and position in the sky change over the course of a month?

In addition to having a research question, inquiry activities must involve students in analyzing relevant data. Consequently, having students conduct research by solely searching library or internet resources does not constitute an inquiry lesson. In these activities, students are gathering information but are not analyzing data to answer their questions of interest. On the other hand, do inquiry-based activities always involve students in collecting their own data? Not necessarily. Students can analyze data collected by the teacher or data available on the internet, provided that students answer their research question through their own data analysis.

Figure 1 (p. 32) presents several examples for teachers to test their understanding of inquiry-based activities. Before continuing with this article, read and consider each of the scenarios in Figure 1 and decide whether or not each is an example of inquiry. After reading through the scenarios, you may recognize that activities 1a, 2a, and 2b do not support inquiry. Example 1a can be a meaningful and engaging hands-on activity, but does not involve a research question. Examples 2a and 2b imply a research question, but do not involve students in analyzing data. Instead, students are merely summarizing the conclusions of others. No doubt these types of activities have a place in the science classroom; however, they should not be confused with inquiry labs.

Examples 1b, 1c, and 2c entail both a research question and data analysis and thus support inquiry learning. In Example 1b, the teacher provides the question, "What are the phases of the Moon?" Student answers to the question are based on analysis of their own Moon observations. In Example 1c, an inquiry lesson is incorporated into a teacher-led demonstration. Although the teacher presents the data using a computer simulation, students are involved as a class in analyzing the virtual observations. Example 2c challenges students to answer the question, "What is El Niño's impact on the climate at a given locality?" Students answer that question based on analysis of data collected on the internet.

All inquiry is not created equal

It is important to realize that not all inquiry activities are created equal. The concept of different levels of inquiry was first described by Schwab (1962). Later, Herron identified three levels of openness for inquiry in science activities (1971). More recently, Rezba, Auldridge, and Rhea (1999) have developed a four-level model of inquiry instruction based on the work by Schwab and Herron. Finally, an even more detailed inquiry rubric can be found in *Inquiry and the National Science Education Standards* (NRC 2000, p. 29, Tables 2–6).

Amount of information provided

Figure 2 (p. 32) presents a modified version of the four-level model of inquiry we use to assess our instructional activities. The four-level model illustrates how inquiry-based activities can range from highly teacher directed to highly student

FIGURE 1

Teacher inquiry self-check.

Which examples constitute inquiry?		
1a. Students complete a Moon phase calendar by ◆ cutting out photographs of the Moon in different phases, ◆ mounting them on a monthly calendar on the proper date, and ◆ labeling each of the eight major Moon phases.	**1b.** After completing a pre-assessment activity on students' knowledge of Moon phases, a student asks about the correct order of Moon phases. The teacher challenges students to determine the sequence of phases by observing the Moon and recording their observations for one month.	**1c.** The teacher begins with the question "Does the Moon rise and set at the same time every night?" Following a brief discussion of the question, the teacher demonstrates the rising and setting of the Moon for several sequential evenings using a computer simulation. The teacher then facilitates a class discussion in which the class concludes that the Moon rises and sets about 50 minutes later each evening.
2a. Students define and describe the El Niño effect by using text and images they find on the internet.	**2b.** Students go to the library to find newspaper accounts describing the impact of El Niño on the California coast. They then summarize what they find in a two-page written report.	**2c.** Students select a location in the U.S. then search the Internet for monthly temperature data of this location for the most recent El Niño year. Students then compare monthly temperature data for the El Niño year to the average temperature data for the past 50 years in order to assess the impact of El Niño on that particular location.

centered, based on the amount of information provided to the student. The salient feature of this model is the question, "How much information is given to the student?"

Using this framework as a guide, lab activities can be designed at varying levels of inquiry, depending on wording and presentation. This model allows the teacher to tailor inquiry lessons to the particular readiness levels of the class. For instance, a Level 1 activity can become a Level 2 by having students complete it prior to learning the targeted concept, and a Level 2 activity can be revised easily to Level 3 simply by removing the procedural directions.

Complexity

The degree of complexity in an inquiry activity also varies, depending on the level of openness and the cognitive demands required (Figure 3). The simplest, Level 1, is sometimes referred to as a confirmation activity. At this level, students are provided the question and procedure, and the expected results are known in advance. For instance, lab activities presented at the end of the chapter to verify a concept that has already been taught fall into this category.

In a Level 2 activity (structured inquiry), students investigate a teacher-presented question through a prescribed procedure. Both Level 1 and 2 activities are commonly referred to as "cookbook labs," because they include step-by-step instructions, but Level 2 activities answer a research question. The difference between a Level 1 and Level 2 activity can be a matter of timing—a confirmation lab can become a structured inquiry lab simply by presenting the lab before the target concept is taught. Note that the majority of laboratory investigations in most textbooks are written at Level 1 or Level 2. Including low-level inquiry activities in the curriculum is not necessarily a problem, as long as they are not used to the exclusion of higher levels. After all, students are able to take greater ownership of their own learning, make authentic decisions, and construct meaning for themselves at the higher levels of inquiry.

A Level 3 activity (guided inquiry), again, features a teacher-presented question but leaves the methods and solutions open to students. This level of inquiry requires students to design or select the procedure to carry out the investigation. Students typically get very little practice in designing their own investigations; therefore, guided inquiries have the potential to take student engagement and ownership of the lab to a new level. Furthermore, guided inquiry activities can be easily created from cookbook labs simply by removing the step-by-step directions and requiring students to come up with their own methods for answering the research question. The teacher should approve student procedures before the investigation is conducted and be sure that proper safety guidelines are followed.

Problems, solutions, and methods are left to the student in a Level 4 activity (open inquiry). Science fair projects are perhaps the most common form of Level

FIGURE 2

Modified version of the four-level model of inquiry.

How much information is given to the student?

Level of inquiry	Question?	Methods?	Solution?
1	✔	✔	✔
2	✔	✔	
3	✔		
4			

FIGURE 3

Levels of inquiry in an effervescent antacid tablet activity.

Reprinted with permission from Rezba, Auldridge, and Rhea (1999).

Inquiry level	Description and examples
1	**Confirmation**—Students confirm a principle through an activity in which the *results are known in advance*. "In this investigation you will confirm that the rate of a chemical reaction increases as the temperature of the reacting materials increases. You will use effervescent antacid tablets to verify this principle. Using the following procedure, record the results as indicated, and answer the questions at the end of the activity."
2	**Structured inquiry**—Students investigate a teacher-presented question through a *prescribed procedure*. "In this investigation you will determine the relationship between temperature and the reaction rate of effervescent antacid tablets and water. You will use effervescent antacid tablets and water of varying temperatures. Using the following procedure, record the results as indicated, and answer the questions at the end of the activity."
3	**Guided inquiry**—Students investigate a teacher-presented question using *student designed/selected procedures*. "Design an investigation to answer the question: What effect will water temperature have on the rate at which an effervescent antacid tablet will react? Develop each component of the investigation including a hypothesis, procedures, data analysis, and conclusions. Implement your procedure only *when it has been approved by your teacher."*
4	**Open inquiry**—Students investigate topic-related questions that are *student formulated* through *student designed/selected procedures*. "Design an investigation to explore and research a chemistry topic related to the concepts we have been studying during the current unit on chemical reactions. Implement your procedure only *when it has been approved by your teacher."*

4 inquiries in science classrooms. Students investigate student-formulated, topic-related questions and use their own procedures. Assuming that students have had experience completing inquiry activities at Levels 1–3, they should be prepared to tackle Level 4 investigations.

Scaffolding inquiry

The inquiry scale should be seen as a continuum, so ideally students should progress gradually from lower to higher levels over the course of a year. Although the goal is to help students develop the skills and knowledge to conduct Level 4 inquiries, they cannot be expected to begin there. Students need practice in inquiry, building up to increasingly open and complex levels. Students will reap as little benefit from being thrown unprepared into Level 4 inquiry activities as they will from being held at low-level activities.

This phenomenon is apparent in the low quality of the science fair and other research projects students may submit at the end of the year. Students cannot be expected to conduct high-level inquiry investigations after having participated exclusively in low-level activities throughout the year. A gradual progression to high-level inquiry, coupled with appropriate scaffolding, will result in greater student success and satisfaction. By understanding first what constitutes an inquiry lesson, teachers will be better able to implement true inquiry-based learning in science activities. Understanding how inquiry can be designed with increasing student involvement will enable teachers to enhance inquiry learning further. Not every worthwhile activity is inquiry based (nor should it be, for that matter), but it is important for teachers to be able to assess those that are while designing and implementing higher levels of inquiry in the classroom. ■

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