



# Breaking into **INQUIRY**

*Scaffolding supports beginning efforts to implement inquiry in the classroom*

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**F**or science teachers, implementing inquiry for the first time can seem intimidating. Inquiry-based curriculum requires teachers to design experiences that engage students in scientific phenomena through direct observation, data gathering, and analysis of evidence. Replacing familiar routines and conventional methods with inquiry may seem outside of a teacher's budget, unpredictable, less structured, and more difficult to manage. Appropriately scaffolded inquiry, however, can provide a smooth transition.

Teachers who are considering inquiry as an instructional technique for the first time should incrementally apply variations of inquiry, depending on the needs and level of their students. The scaffolding described in Figure 1 (p. 50) allows teachers to adjust from highly structured environments and teacher-directed inquiry to less structured environments with student-directed inquiry.

## **Scaffolding inquiry experiences**

Teachers should vary the amount of guidance in their inquiry-based teaching, from "guided" to "open," depending on student skills and needs (NRC 2000). These four different levels of variation can be used by applying the framework in Figure 1—the five essential features of classroom inquiry and their variations of "openness" (NRC 2000). Teachers can successfully start using structured, teacher-directed inquiry (right-hand column of Figure 1) and work up to variations of inquiry that are more open and student-directed (left-hand column). In this way, both teachers and students become accustomed to doing inquiry in an incremental approach, from guided to open degrees of inquiry, building up their confidence and skills through a chosen variation of openness.

### Inquiry level 1 (Figure 1, Column 5)

Teacher-directed variants of inquiry are ideal for teachers breaking into inquiry because they can easily be incorporated into existing curriculums and preferred teaching approaches. The level 1 approach breaks into inquiry through use of the first two essential features of inquiry, *engaging in scientific questions* and *giving priority to evidence in responding to questions*.

At this level, students should focus on a main scientific question to answer based on supplied data. The goal of this approach is for students to understand the importance of evidence, and use the dataset to infer or possibly explain scientific principles that are currently being studied in class. This approach, and all the ones we describe, begins with a question designed to elicit student thinking about the science they are about to experience.

Teachers new to inquiry can easily incorporate a data-based worksheet into their teaching routine to help

students think like scientists as they analyze real data that is tied to their science content. The internet is a ready source of authentic data that is often generated for scientific use (Bodzin and Cates 2002). Data can come from scientific instrumentation directly connected to the internet (real-time data) or scientists who post it for others to access and use.

For example, teachers could have their students look at real-time data for stream flow in their area and ask students if the flow is due to the lack of rain or just seasonal fluctuations (Figure 2, “Water cycle”). Earth science students might plot worldwide earthquake patterns from real-time seismic readings obtained from the internet (Figure 2, “Plate tectonics”). Although students are not collecting the data themselves, they are actually experiencing the scientific evidence required by the second essential feature of inquiry. In a follow-up discussion, the teacher should probe student learning from the data exercise and explicitly connect

**FIGURE 1**

### Essential features of classroom inquiry and their variations.

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Essential Feature	Variations			
1. Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided by teacher, materials, or other source	Learner engages in question provided by teacher, materials, or other source
2. Learner gives priority to <b>evidence</b> in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Learner given data and told how to analyze
3. Learner formulates <b>explanations</b> from evidence	Learner formulates explanations after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence
4. Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	
5. Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to sharpen communication	Learner given steps and procedures for communication
	<b>More</b> -----	<b>Amount of Learner Self-Direction</b> -----		<b>Less</b>
	<b>Less</b> -----	<b>Amount of Direction from Teacher or Material</b> -----		<b>More</b>

**FIGURE 2**

## Using authentic data.

### Water cycle

- ◆ Ask students “Is lack of rain (or excessive rain, depending on the year and location) causing the current change in stream flow?”
- ◆ Hand out a dataset of real-time data from a local river obtained from the website: <http://waterdata.usgs.gov/nwis/rt>.
- ◆ Have students plot or graph data sets of stream flow from this year against the 10-year average and respond to questions on patterns observed.
- ◆ Teacher guides students to make connections with average seasonal rainfall patterns and unusual patterns of rainfall in the region during that year.

### Plate tectonics

- ◆ Ask students “Do earthquakes and other seismic activities happen in a pattern?”
- ◆ Hand out a map of the world and a chart of real-time seismic readings with longitude and latitude coordinates obtained from the website: <http://neic.usgs.gov/neis/epic/epic.html>.
- ◆ Have students plot the earthquakes on their map and respond to questions on patterns observed.
- ◆ Teacher guides students to make connections with observed patterns and tectonic activity along the “Ring of Fire” or Pacific Rim Basin.

student responses and descriptions of data to the principle or concept of study.

This approach stands in vivid contrast to traditional textbooks, in which the evidence for the scientific explanations discussed typically does not appear. Teachers will find that the use of engaging questions and actual evidence will begin moving students from the theoretical world of traditional textbook science to the concrete world of real data about authentic questions.

### Inquiry level 2 (Figure 1, Column 4)

Using demonstrations to aid inquiry can be a next step for teachers who are breaking into inquiry. With a few resources and a little practice, teachers can model an inquiry demonstration in front of students (Chiapetta and Koballa 2002).

In a level 2 approach, teachers should choose a demonstration that models a scientific phenomenon or targeted principle in action (Figure 3). Teachers should not initially explain the demonstration to students but instead introduce it through a focusing question. This question should guide students’ observation during the

**FIGURE 3**

## Predict-observe-explain demonstrations.

### Bernoulli principle: Discrepant event

- ◆ Ask students “What causes an airplane to be able to fly?”
- ◆ Direct students to predict what will happen to a piece of notebook paper as you hold the end of it and blow over the top of it.
- ◆ Have students record and share their observation as you blow over the top of the paper.
- ◆ Ask students to think about their observations and write a possible explanation for them.
- ◆ Discuss student explanations and connect them to the scientifically accepted explanation on fast-moving fluids and pressure differentials.

### Conduction of heat: Data-gathering event

- ◆ Ask students “What’s the best type of insulation for keeping something hot?”
- ◆ Direct students to predict which cup of hot water (glass or Styrofoam) will lose heat faster.
- ◆ Have students record temperature data (thermometer or probe) in tables every minute for 10 minutes.
- ◆ Have students graph data, share results, and provide a possible explanation for the outcome.
- ◆ Tie student explanations to scientifically accepted explanation on conduction of heat and specific materials.

demonstration. This approach to demonstration allows students to follow a cycle of predict-observe-explain or P-O-E (Ebenezer and Haggerty 1999).

Students may be asked to predict the outcome of the demonstration—demonstrations of discrepant events, where the outcome is unexpected and surprising, can be particularly good. In some demonstrations, actual data may need to be recorded by students. Teachers provide structure for what students record and how they manipulate or depict their data. Then, students must consider their findings to formulate their own tentative explanations. Students present these explanations to the class while the teacher acts as a guide, making sure student explanations are logical in light of observable empirical evidence.

After students have had the opportunity to share their explanations, the teacher explicitly makes the connection between the observable phenomenon and the underlying scientific principles. In this last step, however, the teacher must be careful to build on students’ thinking, rather than unveiling the true meaning of the demonstration and thereby placing no value on students’ work.

This approach breaks into inquiry by incorporating another of the five essential features of inquiry, *formulating explanations*. In addition to engaging in scientifically-oriented questions by examining scientific evidence, students learn to develop explanations for the evidence they are considering.

For students, this step is critical to develop strong thinking skills and understand how scientific ideas are moored by scientific evidence. For teachers, mastering the teaching skills necessary to guide student success with this facet of inquiry helps further the transition from a teacher-centered classroom to one where students share in intellectual leadership.

#### FIGURE 4

### Coupled inquiry.

#### Introduction to gas laws.

##### Demonstration

Place a jar or beaker over a lit candle in a pan of water for students to observe the candle go out, bubbles created, and the water level in the jar rise (See Ward et al. 1996).

##### Hypotheses or explanations formed

Students may hypothesize erroneously about the percent of oxygen in the air (21%) being used up in combustion leaving a vacuum that is filled with water. Some may hypothesize correctly that the pressure in the jar initially increases due to heating from the candle, forcing air to bubble out of the jar. When the candle goes out and temperature decreases, the reduced pressure inside the jar allows the higher air pressure outside to force water from the pan into the jar.

##### Further reading

Students turn to their textbook on the designated pages to search for related “literature” that could tie to this phenomenon. Students read passages about gas laws and combustion and revise their initial ideas.

##### Hypothesis testing

Students suggest testing “oxygen hypothesis” or “pressure hypothesis” by using multiple candles, varying jar shape or size, varying water level in pan, among others.

##### Experimentation

Student groups are assigned a hypothesis to test using chosen or prescribed materials available. Students record their data with the pre-approved approach or the teacher-given approach. Each team presents and explains their findings in terms of accepting or refuting their initial hypothesis. The teacher uses results of student experiments to make explicit connections to aspects of the gas laws.

### Inquiry level 3 (Figure 1, Column 3)

With experience in conducting inquiry demonstrations, teachers can next “couple” teacher-led demonstrations with student-led extensions (Figure 4) (Martin-Hansen 2002). Coupled inquiry breaks teachers more deeply into inquiry as students begin to master the fourth essential feature of inquiry, *evaluating explanations and connecting them to scientific knowledge*.

This approach begins with a teacher demonstration and the P-O-E strategy (described in level 2), but afterward, teachers ask students to peruse the “scientific literature” (often their textbook) on how science explains the phenomenon or applied principles in the demonstration. Turning to related literature is what scientists do to inform their ideas and prepare for further research.

After reading the literature, students then revise their ideas in writing based on their reading and share those revisions with the class. The teacher poses how students might test their revised explanations (i.e., formulate a hypothesis) through further exploration with the demonstration materials.

Next, teams of students are commissioned to test their hypotheses after first planning out the needed materials, data to be gathered, and method of analyzing that data. Teachers who want a more structured approach can assign hypotheses, materials, and procedures for students to follow. At this time, teachers may want to discuss how scientists work to refute their hypotheses because data simply affirming a hypothesis do not “prove” it correct (Mannoia 1980).

After testing their hypotheses, student groups report their findings and whether the data support or refute the working hypotheses. Teachers may choose to have groups present their findings more formally in front of the class using an overlay, white board, poster, or PowerPoint presentation. After the presentation, the teacher connects what students have been learning from their inquiries to current knowledge and understanding of the principles or concepts at work.

As with developing explanations, coupled inquiry and evaluation of explanations involve complex, high-level thinking skills. Students have to examine multiple explanations for the evidence at hand to determine which one has the best explanatory power. Students often find that more experimentation is required before they can finalize a satisfactory explanation. At this level, teachers will be pleased to see that students are taking on the nature of true inquiry-based science.

Almost any demonstration of a scientific phenomenon or principle can be extended into student-led inquiry, allowing students to more deeply understand the concept under study. More resources are required for this type of inquiry than with demonstration alone, but this approach moves the science teacher into student-centered inquiry.

#### **Inquiry level 4** (Figure 1, Column 2)

Forms of inquiry in which students generate the questions of interest, develop the methods for exploring them, and generate data for analysis can be very challenging for teachers and students who are new to inquiry. This final form of inquiry breaks into the fifth essential feature of inquiry in which students *communicate and justify their explanations*.

One historical approach to this form of inquiry that is feasible for beginners is the science fair—or similar research—project, which follows an experimental design. With guidance from the teacher, students choose their own research topic, review and read the relevant literature, design the experimental research, analyze the data, and present their results. For a science fair-type project, students have to develop an attractive, cogent display of their process and findings. Students who have become experienced in inquiry throughout the year will be better prepared to produce high-quality projects than those who simply are assigned a project during the final weeks of the year, with no prior experience in inquiry.

Teachers must allocate time for students to prepare, conduct, and complete these projects. Because most student project work generally is done outside of class time, teachers must provide the structure needed through handouts on format guidelines, partial work deadlines, and rubrics used to evaluate their final work (Ambruso 2003).

Teachers should devote in-class time to guiding student preparation for the earlier portions of the project, such as searching for related literature. Teachers can plan product deadlines around direct teachings on important skills needed in the project, such as choosing a topic and designing a hypothesis (Timmons 2003).

Setting up the experiment in school helps the success of the final experimental product, even if much of the work is done outside of school. This approach to the project allows the teacher to teach under structured, whole-class contexts while still having students complete meaningful inquiry that is completely student-directed. Developing the final presentation of the project helps students to see the importance scientists place on formalizing inquiry so that others can review it critically for quality and value.

Even if teachers choose not to set up the competitive aspect of science fairs, having students complete experimental inquiries of their choosing and communicate their findings is a big motivation and can be inquiry at its best!

#### **Becoming an inquiry-based science teacher**

Science teachers know the importance of inquiry-based teaching, but it takes time and practice before teachers feel comfortable and successful doing it. By beginning with teacher-led variants of inquiry, science teachers can

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start to use inquiry within familiar and conventional methods of teaching. For science teachers who are also concerned about planning and management issues, starting to implement inquiry within existing classroom routines and arrangements is essential if inquiry is to occur at all. This is especially true for science teachers new to inquiry. With time and practice, teachers can scaffold their own learning by moving toward student-led variants of inquiry one step at a time. ■

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