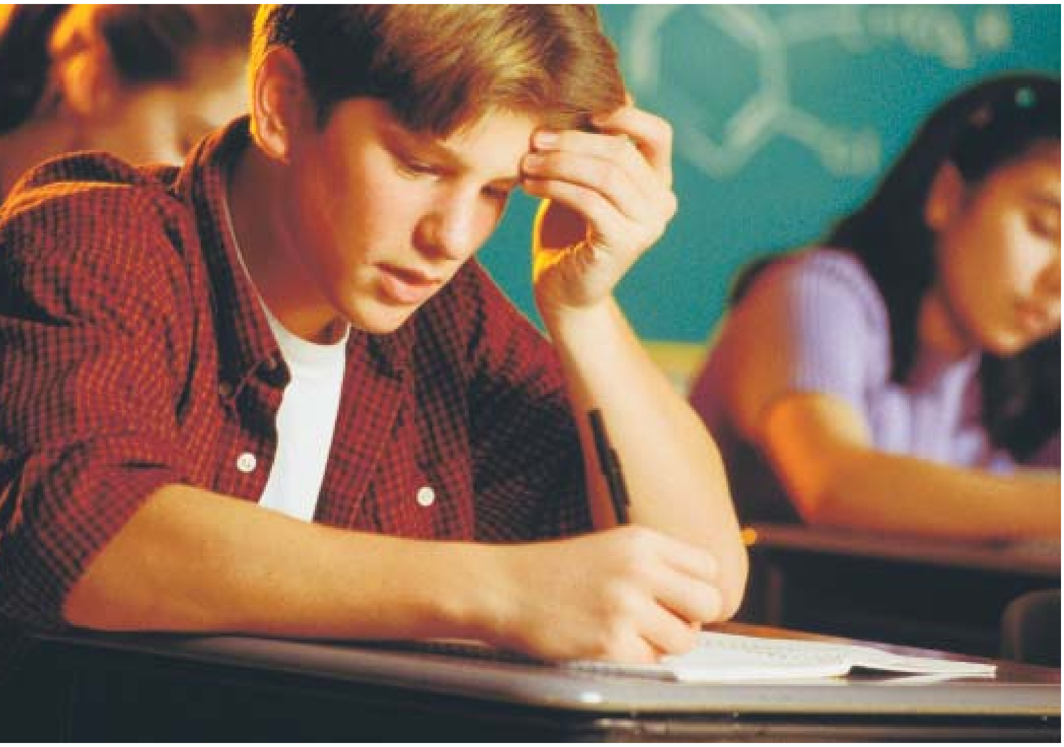
An Activity Model for Scientific Inquiry



A new inquiry model offers a successful guide to how science is really done

William Harwood

Most people are frustrated with the current scientific method presented in textbooks (Bauer 1992; McComas 1996). The scientific method—a simplistic model of the scientific inquiry process—fails in most cases to provide a successful guide to how science is done. This is not shocking, really. Many simple models used in science are quite useful within their limitations. When the simple model fails, however, scientists choose a more sophisticated model to help them in their study.

The Arrhenius theory of acids and bases, for example, is a simple model that works within very strict limits, but ultimately fails. College students in general chemistry are presented with three models of acids and bases (Arrhenius, Lowry-Brønsted, and Lewis). Each model is more sophisticated than the previous one and arose because the simpler model failed in important ways.

The same is true for the scientific method. A new model of the process of scientific inquiry is presented here and is based on the results of interviews with over 50 research scientists from a wide spectrum of disciplines (Reiff, Harwood, and Phillipson 2002). The "Activity model for scientific inquiry" (Figure 1) contains 10 activities in which scientists engage as often as necessary throughout the scientific process. Scientists move among the activities in a pattern dictated by their specific needs. The activity model does not contain a set of steps that define "good science," as suggested by the scientific method. Rather, the model offers activities in which scientists engage (often more than once) to develop and carry through an inquiry.

Explaining the activities

As mentioned earlier, the model contains 10 main points (activities). Nine of the activities center around "Questions," which is placed in the middle of the model because asking questions, both general and divergent, is central to any scientific inquiry.

Another activity, "Defining the problem," refers to limiting the arena the scientist intends to explore. As an example, the question "What is the effect of global climate change?" is very broad. To narrow the focus, a scientist might study the effect of global climate change on oceans or on plant diversity.

Working clockwise around the model, "Forming the question" refers to developing a question that can drive a research study (a convergent process). Next, "Investigating the known" is the process in which scientists consult published books and articles and experts in their area of interest. The need to investigate the known comes up frequently through the course of a scientific inquiry.

In "Articulating the expectation," scientists develop an expectation for their study. For some scientists, this may be a formal hypothesis, but for most it may be a prediction or even an unstated expectation. In the most involved activity, "Carrying out the study," scientists choose the means to investigate their question, gather or create materials, and collect data. While carrying out the study, problems and challenges encountered by scientists often require them to revisit and engage in some of the other activities in the model.

Data can be obtained in a variety of forms depending on the type of study. But scientists need to confirm the validity of the data and "Examine the results." If scientists are uncertain about the data's validity, then the study should be repeated or the design revised.

Once the data is confirmed, the next step is "Reflecting on the findings." Scientists spend considerable time thinking about the meaning of their results—how the results connect with what is known and how to explain them to colleagues. Scientists rarely work in isolation, which means "Communicating with others" is important. Throughout the course of an inquiry, scientists communicate with peers in their lab and colleagues elsewhere. Many inquiries involve collaborative efforts between several scientists, which require good communication skills. Most often, the last activity in a study is a formal communication through an oral or a written presentation.

Throughout the scientific inquiry process scientists emphasize "Observation." Observations may be the starting point for some inquiries but are also accomplished when "Carrying out the study" and "Investigating the known."

Using the activity model

Even though the different activities were just explained following a clockwise order around the model, inquiry follows no single path. To illustrate how the activity model is used, Figure 2 (p. 46) shows a partial pathway a geologist might take while investigating why a forest of trees has died (NRC 2000).

Teachers can also use this activity model in the classroom as a personal framework for the development of lessons and units. Teachers may also want to focus on the tasks involved in specific activities or combinations of activities. For example, searching a certain topic on the Internet is one way students can "Explore the known." Teaching students how to read journals, search the Web, or contact experts are all skills necessary to effectively explore what is known about a topic.

Focusing on an activity within the model provides the opportunity for students to develop and hone skills needed by scientists. Students do not have to engage in a multiweek inquiry project to gain these important skills. For example, teachers could provide students with a case study that produced data and ask them to "Examine the results." Is the data valid? How do they know? "Reflecting on the findings" could be addressed by providing a data set that may have more than one interpretation. How do students resolve the challenge? What would they do to resolve the situation?

The activity model can also provide a framework for structured, guided, or open inquiry lessons. In an open inquiry lesson, for example, the model can help teachers assess whether students are engaged in necessary thinking. Do students move from general questions to forming questions for study? Do they seek known information as needed to help them in their inquiry? Do students

FIGURE 1

Activity model for scientific inquiry.

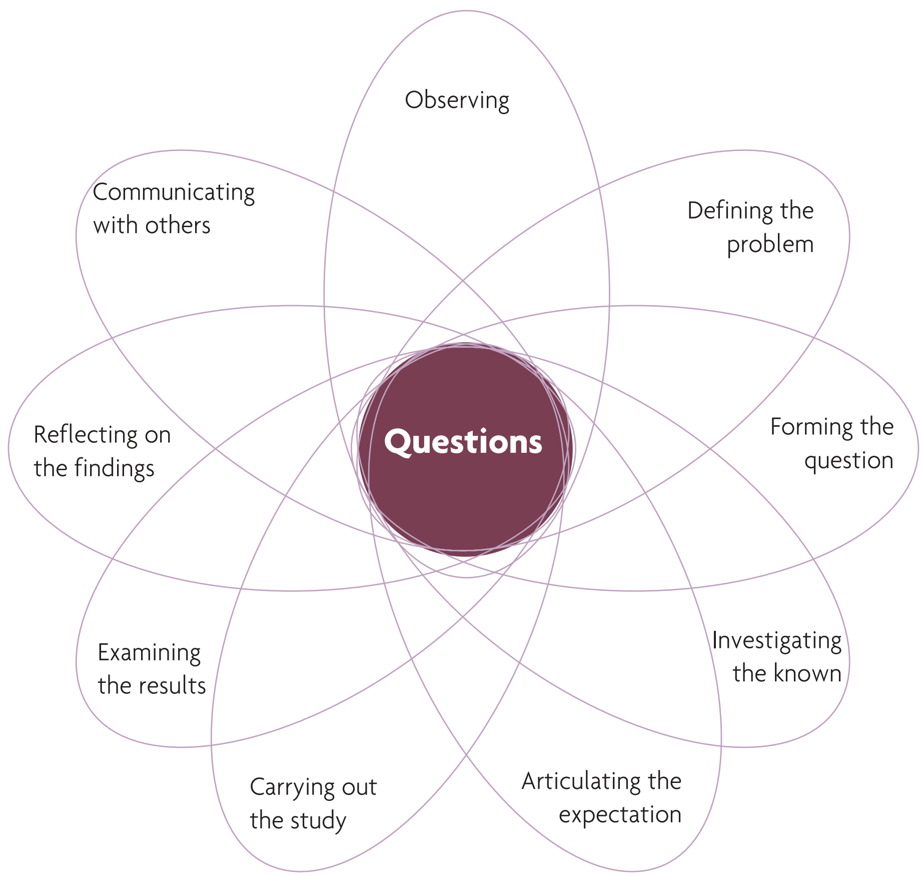


FIGURE 2

Inquiry pathway example.

A geologist might take the following inquiry pathway while investigating why trees in a forest died.

Events	Activity
Discovery of forest of dead cedar trees	Observation
What could have killed so many trees over so wide an area?	Question
Reflecting on knowledge of earthquakes, plate boundaries, coastline subsidence	Investigating the known
Did the trees die at the same time?	Defining problem/Forming study question
Expected carbon dating to answer question	Articulating expectation
Took samples and dated them	Carrying out the study
Found all trees died about 300 years ago	Examining results/Reflecting on findings
Was their death related to nearby volcanic activity or some kind of biological blight?	Forming study question
Mapping indicated no evidence for widespread volcanic deposits	Observation/Carrying out the study
Trees not burned and no evidence of insect infestation	Observation/Carrying out the study
Considering role of salt water	Reflecting on findings/Questions

have a clear expectation from the study? Are they communicating with others throughout the inquiry?

Teachers can also use the model as a guide when providing explicit feedback to students on how they are doing science. When students are working on "Defining the problem" or "Forming the question" used for a term project, they are not preparing to do science but are already engaged in scientific activities. Doing science, according to research scientists, is not just about collecting and manipulating data (Harwood, Reiff, and Phillipson 2002); a lot more thinking and hard work is involved as the activity model shows. Moreover, there is no set of "steps" that define "good science." Each study is unique in the pattern of activities in which the researcher engages.

One of the key faults of the scientific method model is the impression it gives that the only communication scientists engage in is a report (oral or written) at the end of their project. This is far from the case. Often scientists are part of a team working on different aspects of a study and often discuss design issues, known information, and results. In the same way, when students talk with each other about a problem or some aspect of a project, they "Communicate with others." Communicating is not just writing a report or poster at the end of a study. Scientists rarely do their work alone and depend upon colleagues (both in and outside their laboratories) with whom they can exchange ideas and discuss work in progress.

How science is done

The overall intent of this model is to provide students and teachers with a deeper understanding of how science is actually done. With this model students learn that the process of inquiry can follow a series of twists and turns that ultimately can lead to scientific discovery. ■

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