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Teaching Teachers

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Inquiry goes far beyond simply asking questions. Inquiry combines the use of science processes with knowledge of science content.

When pressed to define the term *hypothesis*, most people would reply that a hypothesis is an educated guess, remembering what they were taught when they learned the steps of the scientific method. But what is an educated guess? How is an *educated* guess different from an *uneducated* guess? Consider the following questions:

- How does a prediction differ from a hypothesis?
- What is an inference?
- How does an inference differ from a guess?

More than a decade ago, the American Association for the Advancement of Science (AAAS) (1990) warned that one of the greatest barriers to scientific literacy was the careless use of the language of science. The AAAS strongly advocates the use of clear and precise language when using the highly specialized vocabulary of science.

Since then a great deal of effort has been directed toward establishing science education standards. Implementing these standards will likely result in a more scientifically literate society. A prominent theme through all of the new standards is a push to develop science inquiry in our classrooms.

For example, Teaching Standard B of the *National Science Education Standards* (National Research Council, 1996) mandates proficiency in science inquiry as its central goal. Science teachers should guide and facilitate learning as they focus and support inquiries. As teachers interact with their students, they model the skills of scientific inquiry as well as curiosity, openness to new ideas and data, and skepticism that characterize science. Teachers can also model the accurate language of inquiry.

Inquiry Language

The language of science is precise. The incorrect usage of inquiry language leads to confusion. Science inquiry goes far beyond applying the over-memorized step-by-step scientific method with which so many of us are familiar. The word *inquiry*, as it is commonly used, implies that one is simply asking a question. But in science, inquiry goes far beyond simply asking questions. Inquiry involves combining the use of science processes with knowledge of science content in an effort to develop new science knowledge. Observing, inferring, predicting, and developing hypotheses are science processes that define what a scientist does as the scientist investigates. Although these processes do complement each other, they are not interchangeable.

With clear standards to guide us, I propose that more rigid language standards will communicate the specialized terminology of inquiry with clarity. We might begin by addressing the “hypothesis-is-an-educated-guess” definition that is pervasive in science classrooms across the country. Implying that a hypothesis is some type of guess will not help our students understand the complex nature of inquiry. Instead, help your students think of a hypothesis as an *if-then* statement that is used to guide the development of an inquiry. For example, “*If* the amount of fertilizer in the soil is increased, *then* the amount of plant growth will increase.” Or, “*If* the thickness of a paper towel is doubled, *then* the amount of water that can be absorbed will double.” Although the result of an investigation designed to test a hypothesis might provide evidence in support of the hypothesis, a hypothesis can never be proven true.

Hypotheses, however, can be proven wrong. In fact, often the greatest value of testing a hypothesis is the potential for finding a factor that does not cause an expected change to occur in the investigation.

Predictions and Inferences

All inquiry begins with an observation. Observations often stimulate *why* questions. But meaningful inquiry doesn't begin until the *why* question is transformed into an *inference*. An inference is not a guess. Inferences are explanations for observations that are based directly on observations, and they can be changed or refined as more information becomes available to the observer. For example, "Because the sky is gray and overcast this morning, it will probably rain this afternoon." The second half of the statement is an inference because it is based directly on the observation made in the first half of the statement. It is not a guess. It is not a prediction. It is not a hypothesis.

In the language of science inquiry, *predictions* are forecasts that are made based on many observations. In science, predictions result from comparing an observation to many other similar pieces of data that have been collected over a period of time. Predictions are made based on trends that are observed in a database. Predictions are not guesses.

Predictions cannot be made before data have been collected. All too often, children are asked "to predict what will happen during the activity and write predictions at the top of their data sheets." How can children's inquiry skills improve if we encourage them to make guesses before they make observations? Consider the example of the daily weather reports that we receive each day—they are predictions. These forecasts are based on over 100 years of collected data. Each day the meteorologist collects and compares observations with trends previously recorded in the database. The larger the database, the more confidence we have in the accuracy of the prediction. Of course, the observation on which today's prediction is based becomes part of tomorrow's database. Predictions can be proven wrong, but the probability of a successful subsequent prediction increases as the number of observations grows. Children can learn that predictions do not precede observations, they follow them.

Dorothy Gabel (1993) distinguishes among these terms. "Scientists are interested in not only describing the world around them (observation) but also in explaining why changes occur (inferences) and in forecasting future events (predictions)."

Adjusting Strategies

Confusion often arises in science classes when teachers misuse inquiry terminology while posing questions to students, especially if they begin investigations by asking children to guess. Certainly there are occasions when intuition and guessing are fun, and they can play a role in the inquiry process. But students should not be focusing on guessing when they are investigating an interesting phenomenon in the science classroom. Asking children to make inferences derived from their firsthand observations is a much more meaningful and potentially more productive approach.

Inferences often lead to *operational questions* that are easily tested with concrete materials readily available to the children. These test results become part of a larger database; the data form a baseline from which to make future predictions.

Teachers should carefully model the correct language of inquiry when they pose questions to their students during a science investigation. Planning careful questioning strategies during an inquiry lesson is as important as developing the science content of the lesson. We must say what we mean when we ask questions during a science investigation. For example, don't say, "What do you predict will happen?" when you really mean, "Based on what you observed, can you infer what caused that to happen? Or, don't say, "What is your hypothesis about what will happen?" when you really intend, "Can you guess what is going to happen?" We must recognize when we are asking children to use intuition to make a guess. When that is the case, simply ask, "Can you guess what will happen?" It is important to then follow up the guess with, "Why do you think that will happen?" Or, "What have you observed that makes you say that?" It must be emphasized that science teachers must never use the terms *guess*, *infer*, *predict*, and *hypothesize* interchangeably. They are not equivalent terms.

Teachers should also use great care when using the language of inquiry with their students. Their choice of words must be clear and accurate. Unclear questions perpetuate the double meaning and the misunderstandings that arise from using overly simplified everyday language in place of the precise language of science. The common usage of these terms must never be confused with how the scientist understands the terms. Be purposeful in your questioning, and say what you mean.

I propose to standardize the use of the following definitions. These terms represent important science processes, and the definitions are based on the best that I have gleaned from the literature.

My criteria for settling on each definition were simple and straightforward. I did not use one term to help define another term. *Inference*, *prediction*, and *hypothesis* are all defined in reference to types of observations, not guesses. The term *educated guess* specifically has been eliminated from all of the definitions.

Observation - a piece of evidence that is gained directly through one of the senses; a fact that is nearly impossible to argue.

Inference - an interpretation or an explanation for what is being observed; is based directly on an observation; not a guess.

Prediction - a forecast of a future event based on data already collected; compares a current piece of data with trends that have been observed in the past; not a guess.

Hypothesis - an *if-then* statement of the expected outcome of an experiment; generalization based on what has been observed, rather than what one thinks should be observed; it implies a cause-effect relationship, not a guess.

Guess - using intuition to risk an arbitrary estimate or judgment about something.

Operational question - a *what if* question that enables an investigator to use concrete materials, the manipulation of variables, and measurement to find the answer.

By reducing the reliance on guessing, teachers will be encouraging and modeling the fundamental inquiry skills necessary to do science. Focusing and supporting inquiries with precise inquiry terminology will enable their students to become independent investigators of the natural world.

Frank L. Misiti, Jr. *is a professor in the Department of Early Childhood and Elementary Education at Bloomsburg University in Pennsylvania.*

If you have an idea that you think could benefit your fellow teachers in their understanding of science and/or teaching, send your manuscripts to column editor Michael Kotar, Department of Education, California State University, Chico, CA 95929; mkotar@csu.edu.

Resources

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