Guided Inquiry

by

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Background

Inquiry can be considered a philosophical approach to teaching – teaching any number of subjects, not just science – or can be considered a mere method. In the background here, I will discuss the philosophy of inquiry, and in the method, show one step-by-step process for helping you to start your students carrying out their own inquiry activities.

Note the words I have avoided. I have not used the word "experiment", or the word "laboratory". A laboratory is a place where an experiment is carried out. A laboratory report is the record of that experiment. An experiment is a contrived situation in which one variable is tested against another. Although much of science research is carried out using experiments, other inquiries are not experiments.

As a philosophy, a teacher who believes in inquiry believes that knowledge is a tentative and a social construction. As such, that teacher will want students to be actively engaged in their own learning, and will have the students carrying out investigations to construct their understandings. In science, knowledge is constructed with information from the natural world. Thus, the collection of empirical evidence will always be important to the construction of science knowledge. The teacher will also have the students discussing their findings with the teacher and with their peers, and checking what they have learned with what scientists believe. This is because science knowledge is communally constructed. The teacher will use as little direct instruction as possible.

Direct instruction comprises a number of different methods; what all direct instruction methods have in common is that the teacher has nearly complete control of what and how a topic is learned. When I first learned about inquiry, it was as a method where the teacher designed a recipe for students to follow to affirm a concept presented in class. Thus, the inquiry method I learned was a modification of direct instruction. As a student, when I carried out these activities, I wondered why the teacher would tell me that my answer – which I had found by actually testing the world – was wrong! Surely my answer was as good as his/hers, or as good as the scientists'. This problem is partially circumvented by using only "experiments" that are simple, that students are unlikely to mess up. Unfortunately, this leads to a misunderstanding of the limits of science.

The questions that scientists ask and the ways in which they interpret and analyze the data all come from the scientists' "principles of enquiry" (Schwab, 1960). Kuhn (1960/1973) would say that questions, methods and interpretive framework come from the scientists' paradigm, which is the overarching explanatory principle accepted by that particular community of scientists. This means that science knowledge always comes from a point of view. Scientists seek to affirm their point of view. They are watchful of affirmation to the point sometimes of attempting to disprove their point of view. Nonetheless, they only ask questions from within their point of view. Lewontin (1991) described the search for the cause and then the cure for tuberculosis. Scientists sought a parasitic cause, and found the bacterium which must be present for a person to have tuberculosis. When antibiotics were invented, the cure became available. If scientists had been working with a different principle of inquiry, they might have noticed that most victims of tuberculosis were poor, and lived in crowded conditions, and had poor diets. If the focus of science at the time had been on housing, or healthy diets, the cause of tuberculosis might well have been determined to be these factors. Tuberculosis in England was in decline before the invention of antibiotics; this was because there were less poor people in England, and living conditions were better.

If you are a teacher who has inquiry as a philosophy, you will value the different perspectives that your students bring to a question. You might set out a topic worthy of exploration, but you will leave much else up to your students. You can even leave the topic open if you encourage your students to do independent research projects beyond the curricular material being covered in class.

Inquiry: The Teaching Method

Inquiry as a teaching method was invented by social studies teachers. Students were given data from different countries, and asked to analyze the data to make generalizations and predictions about the people of the countries. Inquiry is a term used broadly to refer to everything from pseudo-experiments where the teacher has the students reify already taught concepts to one in which students have virtually total control.

The parts of a lesson should match the different components of a "laboratory report". Usually, the first part written (or discussed in class) is the problem or question. Often, the problem or question is such that a hypothesis can be written. ENSURE THAT YOUR STUDENTS JUSTIFY THEIR HYPOTHESES. If your students are making random guesses for their hypotheses, they are demonstrating the activity will be meaningless to them. They won't know why they are going through the steps of the procedure. Hypotheses are written as the effect of one variable on another. For example, what is the sunlight on the height of a plant? There are particular materials that are used, there is a method (or procedure) designed for answering the question (or testing the hypothesis), there are data collected or observations made, the data are analyzed or the observations discussed, and there is a conclusion.

Which of these components of the experiment will you control? Which will you leave to your students?

Before deciding how much control to give to your students, consider the pedagogical purpose for doing the experiment, the nature of the materials they will be using, the size of the space they have to work in, the nature of the students you are working with.

Pedagogical purpose of the experiment: if you have just explained a concept to the students, and want them to see the concept at work, you will not use an experiment; rather you use what could more accurately be called a pseudo-experiment. You will choose an activity that is unlikely to go wrong; the students will follow a procedure in recipe-like fashion, all doing the same thing. These kinds of activities are unlikely to change students' preconceptions. Students know the activities are contrived, and they know that they are expected to come up with a particular right answer. There are no surprises for them or for you. Pseudo-experiments are like demonstrations, but the students carry them out themselves. It is certainly better for the students to carry out these pseudo-experiments than to observe a demonstration, and it is better to observe a demonstration than just to hear a lecture.

If however, there are many possible answers to the problem, or if the particular answers do not matter, then you will give more control to your students. If you want your students to learn that there are different explanations for the same problem, or if the problem is complex, you will give more control to your students.

Safety: This is the single most important reason for giving guidance to students. I try to use materials which are as safe as possible, because even in a recipe situation, students will not read the instructions, or will slip while walking past boiling water, or something … Every year, someone somewhere will lean too close to the Bunsen burner, or will add the wrong chemical to a mix. When there is a safety issue, I describe the particular problem to begin with. For example, when I demonstrate dipping money in rubbing alcohol and then lighting it on fire, I show that I hold the bill with forceps and that my hand is not above or below the bill. I do not want the flames burning up on to my hand, nor do I want the rubbing alcohol dripping down onto my hand. (This particular experiment, I have students try out only under close supervision. One group tries it at a time, explaining to the class what their hypothesis is and why their method will test the hypothesis.) I always have hair elastics in my desk drawer, so that a student with long hair can tie it back before working with the Bunsen burner. Etc.

The major hint about safety – writing the safety considerations into a procedure does not mean that students will read, believe, remember. You really have to demonstrate what they have to pay attention to. And even then, you need to have them tell you what they plan to do.

Space: The smaller the space, the less you want your students moving around. Thus, if you have 30 students in a regular sized classroom, you can have them planning much of what they do. But if you have more students, or a smaller classroom, you will want tighter control over what they do so they are not banging into one another. You can still have them carrying out their own activities; you just have to be more organized and ensure that the materials they need are at their station.

Nature of your students: I leave this to you decide. However, I would like to point out that sometimes students act inappropriately because they want more control over their learning. Thus, it is sometimes the students you would least trust to plan their own experiments who will most benefit from it. Try it with some relatively safe activities to see how they do, before making up your mind about whether they can or cannot be trusted out of their desks.

Steps of Inquiry Lessons:
Some teachers like to give their students data sheets, with room for hypotheses, and data tables ready to fill in, and questions to be answered. There is a sample of this kind of lesson – the tracking lesson. Other kinds of inquiry are much more open-ended.

The steps of inquiry lessons are:

- Purpose: The teacher tells the students what they will be learning about and tells them of the interesting implications of the lesson. For example, for tracking, a good tracker can tell the approximate size and weight of an animal s/he tracks from the tracks. The tracker has greater difficulty telling the age of the tracks, but there are clues to this as well. The students will learn, in this lesson, how to estimate size of an animal, and perhaps even speed. Then they will try finding some animal tracks. For this lesson, there is no hypothesis for the students to come up with. (In some cases, the teacher will want the students to decide what they want to study. But there will still be a pedagogical purpose for the teacher to explain to the students.)

In a different case, for example testing the growth of a bean plant according to different variables, the students can hypothesize. The teacher would introduce the purpose of the activity as: to study the effect of light and gravity of the growth of a bean seed. The students would be asked to hypothesize about what effect gravity would have on a young bean plant? Do they think the plant would grow towards or away from the centre of the earth? What effect might light have on the growth of the bean plant?

- Hypothesis: In those activities where there will be a hypothesis, the students should always be expected to make their own hypotheses. This should be done in small groups (pairs), then in whole class discussion. Students should state their hypotheses in terms of the effect of one variable on another, and you must encourage them to justify their hypotheses.
- Procedure: Once students have a clear idea of the purpose of the experiment or study, they should have some idea of how to find the answer. Often, the discussion of different hypotheses will give them ideas for how to test their own hypothesis. Just because they have shown that their hypothesis might be true does not mean they have proved it! The alternative might still be a possibility. They have to rule on the other hypothesis as well as showing that their hypothesis works.

For example, there is a well-known activity, where a match is dropped into a bottle, and a peeled hard-boiled egg is placed on the spout of the bottle. When the match goes out, the egg pops into the bottle. This was explained to me as the result of oxygen being consumed by the flame. An alternative is that the match heated (causing expansion of) the air, which was able to escape past the egg out of the bottle. When the match went out, the air contracted again, and the egg was drawn into the bottle. A student's procedure must test expansion and contraction without any oxygen being consumed, or test the consumption of oxygen without any expansion or contraction.

- Materials: Once students know what they plan to do, they can make a list of the materials they will need. Sometimes it helps to tell them what materials are available before they design their procedure (one small way you can retain control!) However, often the materials they need can be brought from home. If students are testing different kinds of food for starch and fat, you would encourage them to bring some from home.

Encourage your students to write what they plan to do and to write a list of what materials they need. For those who prefer to draw, encourage them to do both.

- Data: Before students begin the experiment, remind them of all safety precautions. If they are working with chemicals, they should be wearing safety glasses. If they are working with Bunsen burners, they should have their hair tied back. Etc. Then they are to carry out their experiment. Since they designed the procedure, they should know what data to collect. They should have a plan to record their data.
- Analysis: Again, students should know what they are trying to find. They might need assistance in steering away from their affirmation bias, however.

I have seen many students test one bean against another, with bean A watered with vinegar (to simulate acid rain) and bean B watered with pure distilled water. When bean A thrives and bean B dies, the student will start another bean B and another, until one does well. This is not a fair test. The students need to be reminded that they should start with more than one of each bean plant, just in case one of them is a dud. And, it might turn out that vinegar is good for germination of bean seeds.

- Conclusion: When your students have finished their study or experiment, they must discuss their results with one another. They must find out who had the same results, who had different results, why the results might have been different. They must interpret the results according to their original question. What do the results mean? The results will almost certainly lead to another question, and the process begins again.

Notice that the class discussion of the conclusion is the debrief of the lesson. This is when the meaning of the lesson can be put into the context of the unit as a whole.

A big advantage of inquiry where students have most of the control over the activity is that students of different cultural backgrounds have different principles of inquiry. Western science has answered many questions, but has always answered questions of interest to Western males. The methods of science – looking for evidence in the empirical world to answer our questions – can be used by different cultures. If you have a class with students of different cultures, encourage the students to talk about questions of interest to them. You must listen carefully, and be watchful. Often, minority students are quiet in class. When do you notice that they are paying close attention to you? Is it because of what you are talking about or how you are acting that is of interest to them?