The Inquiry Process

Productive, inquiry-based science study enables children to realize they can raise and answer questions themselves. The scientific method is the inquiry process by which scientists raise and attempt to answer new questions.

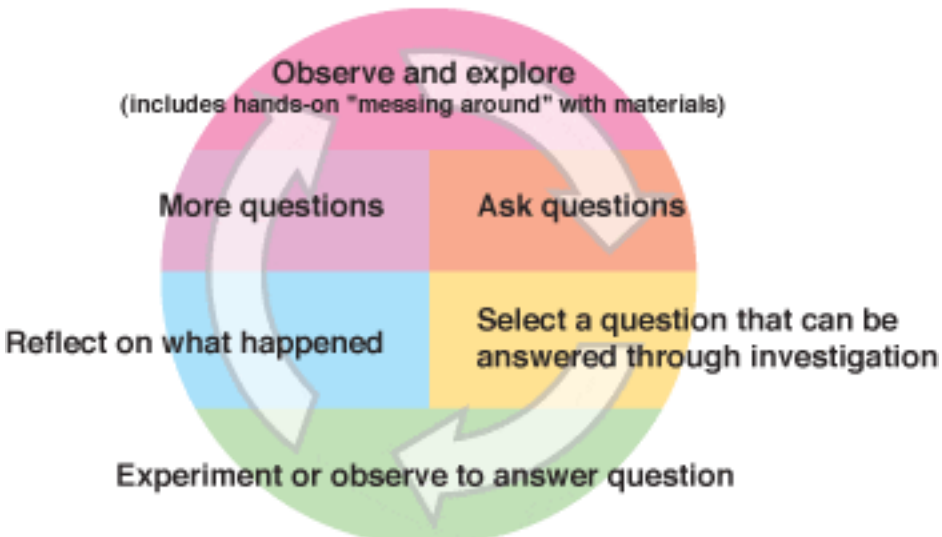


Figure 1.The inquiry process

Raising questions

What do I already know?

Before students generate questions to investigate, it is a good idea to have them review what they know, or think they know, about the topic under study. This focuses student interest and attention, reveals misconceptions, and allows the teacher to assess where the inquiry should or might lead. This is the first part of the KWL process: K = What do I know? W = What do I want to know? L = What did I learn?

What do I want to know? - Exploring

Questions naturally arise from experience with the world around us. While pre-school children are usually founts of questions, school experiences often discourage children from questioning, especially when the classroom climate emphasizes getting the right answer. Most teaching formats involve teachers posing the question and students trying to answer it. The teacher who wants to encourage student inquiry may find it difficult to get students to raise any questions at all, much less any interesting or productive questions that could actually be investigated. A good tool to address this problem is the "I notice/I wonder" chart. For older students, the columns are labeled "Observations" and "Questions." In the left hand column, students write down things they notice that are interesting to them; in the right hand column they note the corresponding question(s) that the observation provokes.

I notice	I wonder
Spiders	What do they eat?
Seeds	What kind are they?

Figure 2. I notice/ I wonder.

In order to generate questions, students need to have hands-on or observational experience with the materials or phenomenon first. The younger the child, the longer the time needed for the hands-on exploration. The teacher sets parameters for questioning with his/her decisions about what materials or, in the case of schoolyard ecology, what areas or aspect of the school grounds, to present for exploration, and by what tools he/she makes available during the exploratory phase. For example, if the topic is light, you might provide flashlights and mirrors and a darkened room for free experimenting before the children start generating questions. If the topic is food chains, you might select one or more areas of the schoolyard, provide hand lenses, and challenge students to find one species interacting with another, interesting patterns, or simply note anything that is of interest to them.

Kinds of questions

Sometimes the stumbling block to inquiry is not getting students to raise questions, but the kinds of questions they raise. Questions nearly always fall into one of three categories: questions that can be investigated, questions that can be answered by doing research (looking up the answers), and questions to which the answer is highly complex or not known.

Other kinds of student questions are: comments expressed as questions (which can be responded to in a way that encourages students' curiosity and reinforces making observations), requests for simple facts (which can be given if the teacher knows the answer), and philosophical questions, which are often "why" questions to which there is no answer.

However, many questions that students phrase with a "why" can be restated so that they can be investigated. If you can turn the question into a "how would you?" or a "what would happen if?" question, it can usually be investigated. To turn questions, you need to do a "variables scan" (Harlen, 2001). That means breaking the big, complex "why" question into smaller, component parts. Variables, in this usage of the word, are individual aspects of the question that can be investigated through observation, measurement, or experimentation.

For example, let us imagine that a student asks, "Why do plants grow?" Variables immediately apparent are factors such as light, water, soil, and nutrients. We might then rephrase the question into several "what would happen if?" questions that can be investigated by students: "What would happen if we stop giving plants water?" "What would happen if we give plants more light?" "What would happen if we add nutrients to the soil around a plant?" "What would happen if we remove the plant from soil and place it in water?" As basic principles are discovered, the investigation can be refined and made more challenging as students try to find the optimal growth conditions for the plants with which they are working.

The example above is one of a manipulative experiment— we can manipulate, or change, the factors that affect plant growth. Outside in your habitat area, your ability to manipulate conditions may be limited by concerns about damaging the plants and animals that live there. But the options for observational experiments in the habitat are almost unlimited. An observational experiment is one in which we observe how things actually operate in the natural world in order to answer our question. Let us imagine we want to address the question, "Why do plants grow?" with an investigation in the habitat area. We also do not want to kill any of the plants. The same factors or variables affect plant growth in the habitat—light, water, soil, and nutrients. Instead of manipulating one of those factors to see what happens to the plants (we could do that, also, but we might wind up killing some of the plants!), we can compare the growth rates of plants of the same species at different locations in the habitat under existing conditions. In order for the comparisons to be meaningful, we will also have to know the differences in light, water, nutrient levels, and soil type to which each plant is exposed.

Fair testing

The observational experiment described above is a good example of another problem that teachers usually encounter when attempting inquiry science with students. That is, how do you structure the experiment to make sure that you are testing only one factor? Students will need guidance in structuring their first experiments so that they are fair tests (tests of only one variable factor), but as they become more experienced with inquiry, they will become more adept at designing fair tests.

In the observational example above, there are four factors that could affect the growth rates of plants in the habitat— light, water, nutrient level, and soil quality. If we find a difference in the growth rates of plants of the same species in different locations, how can we determine which of the four factors is responsible? In fact, we can't identify any one factor as responsible unless we find that some factors are the same for all plants. Let us say that we have four brittlebush plants in the habitat, and we find that the soil in which they are planted has the same texture, and they all receive the same amount of water through a drip irrigation system, and the same amount of sunlight. We can then hypothesize that they are receiving different levels of nutrients, and check the hypothesis by using a soil nutrient test kit. (We might then further refine our experiment by giving extra nutrients to some of the plants and finding out what happens.) But suppose that soil texture and water levels are the same for all plants, but nutrient and light levels are different. We could try shading the plants in the sunnier location and measuring how that affects their growth rate. Or, we could try adding nutrients to the soil of the slower growing plants to see if they catch up with their faster growing relatives. But we cannot do both those things at the same time! We have to do one thing and measure the results, and then the other thing and measure the results. In this case, we are dealing with multiple hypotheses, because there might be more than one factor affecting plant growth. In order to get an answer to our question, we have to test each hypothesis. But we cannot test more than one hypothesis in each experiment. So we will need to run more than one experiment to find the answer to our question. This is why it is important to let students generate multiple hypotheses. Experiments to test different hypotheses can be run at the same time by different groups of students, or sequentially. Sometimes what is learned in the first experiment will help us design our second experiment more effectively.

If you are an elementary or middle school teacher, we highly recommend that you consult *Primary Science: Taking the Plunge*, by Wynne Harlen, to learn more about student questioning and fair testing.

More on questions

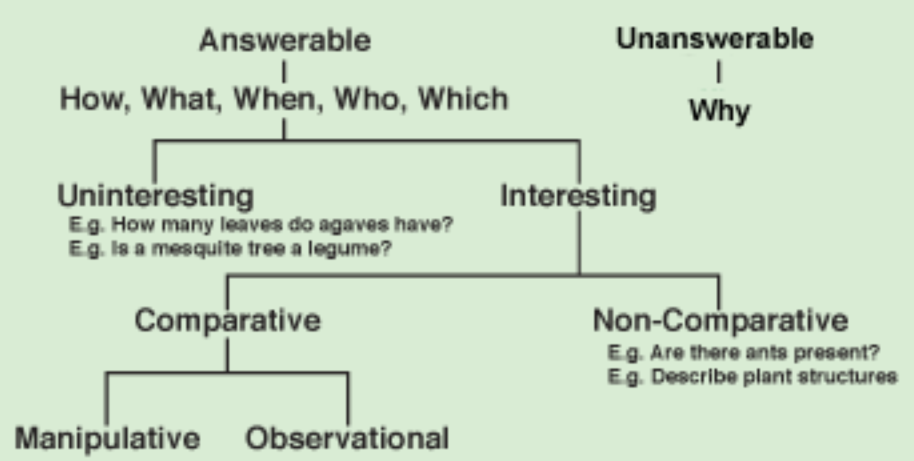
You may have noticed that the question about why plants grow could be answered either by student investigation or by looking up the answer. Many questions that students ask will fall into both categories. Obviously, there is not enough time to conduct an investigation into every interesting question that students raise. It is up to the teacher to choose which questions should be answered with a full investigation, and to help students choose appropriate resources to find answers to questions that will not be investigated. By doing just one or two full investigations each year, you will enrich your students' education tremendously.

When considering which questions to investigate, you need criteria for what makes a question investigate-able in your classroom. Some criteria to consider are:

- Can the question be answered by making observations, collecting data, making measurements, changing variables?
- Can we narrow the question to look at a single thing (fair testing)?
- Can we conduct the investigation safely?
- Do we have or can we acquire the necessary materials?
- Does the investigation fit the developmental level of the children?

The Question Tree below is a helpful tool as you consider what kinds of questions you will investigate with your students.

Figure 3. Question Tree



Reflecting on what has been learned

The last part of the KWL sequence is, "What did I learn?" Reflecting on what was learned in the course of an investigation/experiment is an integral part of the inquiry process. It is the part that leads to the generation of more questions for investigation. It can also be a self-evaluation tool for students. Reflection should focus not only on what was discovered, but also on the process of the investigation itself: What did we do that worked? What didn't work and why? What could we change next time to get more accurate results? And so forth.

Inquiry is not a linear process, it is a circular one. We do not start at Point A and arrive at Point B and stop. Because what we have learned on the journey from Point A to Point B has made us curious about a new question, C. So off we go again on another adventure. No scientist ever finishes his work, just as no human being ever stops learning.

For a more in-depth look at inquiry, click on **scientific method**.

Resources

The following books are recommended to learn more about doing science inquiry with students. All are available in the SCENE library.

Harlen, Wynne. *Primary Science: Taking the Plunge*. Second edition. Heinemann, 2001. 140 pp. The best book we have read so far on how to do inquiry-based science with children ages 5 to 12.

Doris, Ellen. *Doing What Scientists Do: Children Learn to Investigate Their World*. Heinemann, 1991. 194 pp. As the back-cover review states: "This is a splendid down-to-earth book for any teacher interested in doing science in elementary years but unsure how to go about it."

Bourne, Barbara, ed. *Taking Inquiry Outdoors: Reading, Writing, and Science Beyond the Classroom Walls*. Stenhouse Publishers, 2000. 142 pp. Case studies by different teachers provide models and ideas for how inquiry can be done productively outdoors.

Basile, Carole G., Jennifer Gillespie-Malone and Fred Collins. *Nature at Your Doorstep*. Teacher Ideas Press, 1997. 161 pp. These activities for K-6th grade students are a good starting point for exploring the ecology of your school yard, and provide practice with the inquiry process.

Hall, Jody S. et al. *Organizing Wonder: Making Inquiry Science Work in the Elementary School*. Heinemann, 1998. Case studies, from a group of teachers who tried to implement the ideas in *Primary Science: Taking the Plunge* in their own classrooms, provide examples of student explorations of physical science phenomena, as well as reflections on the process of teaching through inquiry and overcoming the stumbling blocks to doing so.

Rueff, Kerry. ***The Private Eye****, (5X) Looking/Thinking by Analogy*. The Private Eye Project, 1998. 229 pp. An excellent resource for getting started with hands-on science and connecting it to all areas of the curriculum. "The Private Eye is a program about the drama and wonder of looking closely at the world, thinking by analogy, and changing scale. It's also about theorizing. Designed to develop higher order thinking skills, creativity and scientific literacy— across subjects, it's based on a simple set of 'tools' that produce 'gifted' results. Hands-on, investigative, The Private Eye, using everyday objects, a jeweler's loupe, and simple questions— accelerates science, writing, art, math and social studies, as well as vocational and technological education. It builds communication, problem solving, and concentration skills. For K-16 through life, all levels, The Private Eye develops 'the interdisciplinary mind.'" (from the back cover)

National Research Council. ***Inquiry and the National Science Education Standards: A Guide for Teaching and Learning***. National Academy Press, 2000. 202 pp. A practical guide for teaching science through inquiry. Chapter 3, Images of Inquiry in K-12 Classrooms, provides helpful models for putting inquiry into practice in the classroom. You can read this book online at: **http://books.nap.edu/html/inquiry_addendum/**

Exploratorium Institute for Inquiry provides resources, inquiry activities, workshops, programs, and an intellectual community of practice to afford educators a deep and rich experience of how inquiry learning looks and feels.