SCIENCE INVESTIGATIONS

Thinking Like a Scientist

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WHAT IS SCIENCE?

From the beginning of human history, people have asked questions about natural phenomena. Science is a process for answering these questions through investigation. It is not a rigid set of procedures, but rather a broad approach to investigation that begins with questions like: Why? What’s going on? How is this explained? This approach leads an investigator to reasoned, evidence-based answers to those questions.

Also called “The Scientific Method” or “Scientific Inquiry,” science investigations use a logical and rational order of steps by which scientists come to conclusions about the world around them. Through observations, questions, hypotheses, data collection, and logical reasoning, the process of science serves as a helpful framework to ensure that scientists can be confident in the answers they find.

SCIENCE INVESTIGATIONS INVOLVE BOTH KNOWLEDGE AND SKILLS

When conducting an investigation, a scientist must weave together an understanding of basic science concepts such as how ecosystems function, the behavior and habitat needs of individual species, and how nature changes over time. To do this, they use skills such as asking questions, interpreting data, and supporting arguments with evidence.

ANYONE WHO PRACTICES THE PROCESS OF SCIENCE IS A SCIENTIST!

When participating in scientific investigations, learners make observations of the world around them which leads them to ask questions about what they see. They think of possible explanations, or hypotheses, for their questions, and gather evidence that might lead them to favor one explanation over another. Ideally, they design experiments or conduct other kinds of study to answer their questions, and share their findings with their peers. Investigations are often cyclical, with reflections on the experience sparking new questions for study. That’s what being a scientist is all about!

When youth take on the role of scientist, they come to understand the very nature of science. In addition to learning about science, they are learning by doing science. They begin to acquire the thinking skills important in everyday life, and may even set on a course toward pursuing careers in science (National Research Council, 2000).

A STEPWISE PROCESS

Science investigations can be both quite simple (e.g., ask questions and methodically pursue answers) and overwhelmingly complex (e.g., a ten-step process with piles of data). Either way — and anywhere in between — doing science boils down to the process of asking questions based on observations and methodically pursuing answers (See Figure 1). Across all these steps, a scientist often draws on creative thinking to challenge assumptions, draw connections, generate ideas, realize new insights, and create new procedures.

After observing monarch larvae in a field of milkweed, youth naturally become more curious and ask questions about what they see.
FIGURE 1. Scientific discoveries are made through the process of investigation, though scientists often use the word “research” or “the scientific method” to describe what they do. Investigations involve detailed examination of phenomena with the goal of discovering and interpreting new knowledge, whether the knowledge is new to humankind, to a small group of people, or just to the person doing the research.
A scientific investigation begins when someone focuses attention on the world around them and uses their senses to experience what’s there. They may compare what they see to what they already know or to other things they see. They may record notes or illustrations about their observations in a journal.

Observations naturally trigger curiosity. At this stage, observers become scientists. When they pose questions, they may challenge assumptions, synthesize observations, or infer that what they see involves more than meets the eye. Although scientists may ask thousands of questions, they must narrow down their specific queries to pursue answers.

Scientists will use logical reasoning to theorize about what answers they might find, and whether and why they think some of these answers might be more likely than others. Often, scientists will identify factors they think will influence whether one potential answer is more likely.

In this stage, scientists organize a systematic method for collecting data that will confirm or contradict their hypotheses. They may use tools such as thermometers, microscopes, chemical tests, or binoculars; or they may simply use their own eyes and ears to collect information. They must remain as objective and consistent as possible while collecting data to ensure that their evidence is sound, and not biased in some way.

Once the data are gathered, scientists summarize their data to report statistics or evidence about what they’ve found. This kind of analysis can include both very simple summaries or complex analyses that help determine the statistical significance of the data. Then, they apply their best logical reasoning to give the information meaning.

When considering all the data, scientists determine which hypothesis is best supported by the evidence. They often will use graphs or tables to explain to others what they found and what they think their findings mean.

Scientists must continually re-evaluate their assumptions, consider alternatives, identify problems with their process, seek input, troubleshoot, and ask more questions. At any point, they may rethink their investigation plan and take a new direction with new questions. The diagram’s dotted arrows illustrate this critical reflection.

**FACILITATOR SKILLS THAT FOSTER SCIENTIFIC THINKING**

Ideally, learning about this process should be driven by the learners themselves, so instructors must take a back seat to their participants’ curiosity. The instructor simply facilitates the learning process. This means a lesson plan for an investigation might look more like a “facilitation plan” in which the instructor prepares for the many different ways an activity may turn out (Step-by-step facilitation-plan creation, 2004). Such a plan focuses on the essential learning points and habits of mind the youth should take away from the experience, while still allowing the learner to drive the process.

Facilitating scientific inquiry experiences requires flexibility, patience, tolerance of ambiguity, and an emphasis on youth skill building. When learner-driven inquiry takes place, instructors become learners too. And not just in the content area, but by gaining a deeper understanding of their students’ thinking processes — as well as the process of science itself.
INQUIRY AND K-12 ACADEMIC STANDARDS

Although the specific requirements vary from state to state, all students must learn the process of science in one form or another. Both the Next Generation Science Standards (National Research Council, 2013) and the National Science Education Standards (National Research Council, 2000) outline foundational concepts and science practices that guide science education in both formal and non-formal settings. The process of doing science is both a teaching method and a learning goal. Specific standards increase in complexity from kindergarten through grade 12, however, all age levels must ask questions, plan and implement investigations, and communicate results.

While each step in a scientific investigation is crucial for developing a clear grasp of science, any one lesson or activity might not embody all the steps. Depending on the learning setting, it may not be possible or appropriate to carry out the entire learner-driven investigation process. In some cases, it may be useful for the instructor to guide the process by asking a provocative question or providing a pre-determined set of data in the interest of dedicating more learning time to other steps in the process.

SUMMARY

Investigations are driven, as much as possible, by a learner’s questions rather than by what the instructor wants to teach. At the heart of science, investigations draw on and feed a learner’s natural curiosity. Through the experience of conducting science investigations, learners develop essential skills: those that help them learn how to learn.

REFERENCES


Through Extension’s Driven to Discover: Enabling authentic inquiry through citizen science project, middle school students learn to think like scientists. Find curricula, videos and other teaching resources at extension.umn.edu/citizenscience.