Teaching The Science Process Skills

What Are the Science Process Skills?

Science and teaching students about science means more than scientific knowledge. There are three dimensions of science that are all important. The first of these is the content of science, the basic concepts, and our scientific knowledge. This is the dimension of science that most people first think about, and it is certainly very important.

The other two important dimensions of science in addition to science knowledge are processes of doing science and scientific attitudes. The processes of doing science are the science process skills that scientists use in the process of doing science. Since science is about asking questions and finding answers to questions, these are actually the same skills that we all use in our daily lives as we try to figure out everyday questions. When we teach students to use these skills in science, we are also teaching them skills that they will use in the future in every area of their lives.

The third dimension of science focuses on the characteristic attitudes and dispositions of science. These include such things as being curious and imaginative, as well as being enthusiastic about asking questions and solving problems. Another desirable scientific attitude is a respect for the methods and values of science. These scientific methods and values include seeking to answer questions using some kind of evidence, recognizing the importance of rechecking data, and understanding that scientific knowledge and theories change over time as more information is gathered.

SIX BASIC PROCESS SKILLS

The science process skills form the foundation for scientific methods. There are six basic science process skills:

- Observation
- Communication
- Classification
- Measurement
- Inference
- Prediction

These basic skills are integrated together when scientists design and carry out experiments or in everyday life when we all carry out *fair test* experiments. All the six basic skills are important individually as well as when they are integrated together.

The six basic skills can be put in a logical order of increasing sophistication, although even the youngest students will use all of the skills alongside one another at various times. In the earliest grades students will spend a larger amount of time using skills such as observation and communication. As students get older they will start to spend more time using the skills of inference and prediction. Classification and measurement tend to be used across the grade levels more evenly, partly because there are different ways to do classifying, in increasingly complex ways, and because methods and systems of measuring must also be introduced to children gradually over time.

Integrating the basic science process skills together and gradually developing abilities to design fair tests is increasingly emphasized in successive grade levels, and is an expectation of students by fourth grade. The Virginia Standard of Learning (SOL) 4.1 for fourth-graders includes, for example, creating hypotheses and identifying and manipulating variables in simple experiments. At this level, the students are beginning to really ask and answer their own questions in a scientific sense. The following *Designing an Experiment* and *Analyzing Experimental Data* sections will focus on using the integrated science process skills to design experiments and reach conclusions.

In the Virginia Standards of Learning, the first science SOL (x.1) at every grade level K – 12 tells which of the science process skills should be introduced and emphasized at that grade level. For grades K–6, where the SOL at each grade includes content from all areas of science, organized in strands across these grade levels, the science process skills SOL falls in the Scientific Investigation, Reasoning, and Logic strand. For grades 7–12 (Life Science, Physical Science, Earth Science, Biology, Chemistry, then Physics) the SOL are no longer organized in vertical strands, but the first SOL at each of these grade levels still defines the science process skills to be taught and practiced at that grade level. For all grade levels K – 12, the intention is that the science process skills be taught and practiced by students in the context of the content SOL for that grade level. Students will work on different content areas of science during the year, and all year long they will continue to use and develop further the science process skills for their grade level.

Science Begins With Observation

Observing is the fundamental science process skill. We observe objects and events using all our five senses, and this is how we learn about the world around us. The ability to make good observations is also essential to the development of the other science process skills: communicating, classifying, measuring, inferring, and predicting. The simplest observations, made using only the senses, are qualitative observations. For example, the leaf is light green in color or the leaf is waxy and smooth. Observations that involve a number or quantity are quantitative observations. For example, the mass of one leaf is five grams or the leaves are clustered in groups of five. Quantitative observations give more precise information than our senses alone.

Not surprisingly, students, especially younger children, need help in order to make good observations. Good, productive observations are detailed and accurate written or drawn descriptions, and students need to be prompted to produce these elaborate descriptions. The reason that observations must be so full of detail is that only then can students increase their understanding of the concepts being studied. Whether students are observing with their five senses or with instruments to aid them, we can guide them to make better more detailed descriptions. We can do this by listening to students' initial observations and then prompting them to elaborate. For example, if a student is describing what he or she can see, they might describe the color of an object but not its size or shape. A student might describe the volume of a sound but not its pitch or rhythm. We can prompt students to add details to their descriptions no matter which of the five senses they are using. There are other ways that we can prompt students to make more elaborate descriptions. For example, if something is changing, students should include, before, during, and after appearances in their observations. If possible, students should be encouraged to name what is being observed.

Observation and Communication Go Hand in Hand

As implied already, communication, the second of the basic science process skills, goes hand in hand with observation. Students have to communicate in order to share their observations with someone else, and the communication must be clear and effective if the other person is to understand the information. One of the keys to communicating effectively is to use so-called referents, references to items that the other person is already familiar with. For example, we often describe colors using referents. We might say *sky blue*, *grass green*, or *lemon yellow* to describe particular shades of blue, green, or yellow. The idea is to communicate using descriptive words for which both people share a common understanding. Without referents, we open the door to misunderstandings. If we just say *hot* or *rough*, for example, our audience might have a different idea of how hot or how rough. If a student is trying to describe the size of a pinecone they might use the size of his or her shoe as a referent. The pinecone could be either larger or smaller than his shoe.

The additional science process skill of measuring is really just a special case of observing and communicating. When we measure some property, we compare the property to a defined referent called a unit. A measurement statement contains two parts, a number to tell us *how much* or *how many*, and a name for the unit to tell us how much *of what*. The use of the number makes a measurement a quantitative observation.

Students can communicate their observations verbally, in writing, or by drawing pictures. Other methods of communication that are often used in science include graphs, charts, maps, diagrams, and visual demonstrations.

Classifying Into Groups

Students in the early grades are expected to be able to sort objects or phenomena into groups based on their observations. Grouping objects or events is a way of imposing order based on similarities, differences, and interrelationships. This is an important step towards a better understanding of the different objects and events in the world.

There are several different methods of class-ification. Perhaps the simplest method is serial ordering. Objects are placed into rank order based on some property. For example, students can be serial ordered according to height, or different breakfast cereals can be serial ordered according to number of calories per serving. Two other methods of classification are binary classification and multistage classification. In a binary classification system, a set of objects is simply divided into two subsets. This is usually done on the basis of whether each object has or does not have a particular property. For example, animals can be classified into two groups: those with backbones and those without backbones. A binary classification can also be carried out using more than one property at once. Objects in one group must have **all** of the required properties; otherwise they will belong to the other group.

A multi-stage classification is constructed by performing consecutive binary classifications on a set of objects and then on each of the ensuing subsets. The result is a classification system consisting of layers or stages. A multi-stage classification is complete when each of the objects in the original set has been separated into a category by itself. The familiar classifications of the animal and plant kingdoms are examples of multi-stage class-ifications. A useful activity for younger children could be to create a multi-stage classification of some local animals using physical and/or behavioral similarities and differences.

The Virginia Science SOL match the different classification skills to the different grade levels. In kindergarten, children are expected to sequence a set of objects according to size. The kindergarteners are also expected to separate a set of objects into two groups based on a single physical attribute. (See Science SOL K.1.) In first grade, students should classify and arrange both objects and events according to various attributes or properties (1.1). In second grade, students should classify items using two or more attributes (2.1). In third grade, students should classify objects with similar characteristics into at least two sets and two subsets, and they should also sequence natural events chronologically (3.1). In fourth grade, students should classify data to create frequency distributions (4.1); in fifth grade, students should identify rocks, minerals, and organisms using a classification key (5.1); and in sixth grade, students should develop a classification system based on multiple attributes (6.1).

Making Inferences and Predictions

Unlike observations, which are direct evidence gathered about an object, inferences are explanations or interpretations that follow from the observations. For example, it is an observation to say *an insect released a dark, sticky liquid from its mouth*, and it is an inference to state, *the insect released a dark, sticky liquid from its mouth because it is upset and trying to defend itself*. When we are able to make inferences, and interpret and explain events around us, we have a better appreciation of the environment around us. Scientists' hypotheses about why events happen as they do are based on inferences regarding investigations.

Students need to be taught the difference between observations and inferences. They need to be able to differentiate for themselves the evidence they gather about the world as observations and the interpretations or inferences they make based on the observations. We can help students make this distinction by first prompting them to be detailed and descriptive in their observations. Then, by asking students questions about their observations we can encourage the students to think about the meaning of the observations. Thinking about making inferences in this way should remind us that inferences link what has been observed together with what is already known from previous experiences. We use our past experiences to help us interpret our observations.

Often many different inferences can be made based on the same observations. Our inferences also may change as we make additional observations. We are generally more confident about our inferences when our observations fit well with our past experiences. We are also more confident about our inferences as we gather more and more supporting evidence. When students are trying to make inferences, they will often need to go back and make additional observations in order to become more confident in their inferences. For example, seeing an insect release a dark, sticky liquid many times whenever it is picked up and held tightly will increase our confidence that it does this because it is up-set and trying to defend itself. Sometimes making additional observations will reinforce our inferences, but sometimes additional information will cause us to modify or even reject earlier inferences. In science, inferences about how things work are continually constructed, modified, and even rejected based on new observations.

Making predictions is making educated guesses about the outcomes of future events. We are forecasting future observations. The ability to make predictions about future events allows us to successfully interact with the environment around us. Prediction is based on both good observation and inferences made about observed events. Like inferences, predictions are based on both what we observe and also our past experiences the mental models we have built up from those experiences. So, predictions are not just guesses! Predictions based on our inferences or hypotheses about events give us a way to test those inferences or hypotheses. If the prediction turns out to be correct, then we have greater confidence in our inference/hypothesis. This is the basis of the scientific process used by scientists who are asking and answering questions by integrating together the six basic science process skills.

In summary, successfully integrating the science process skills with classroom lessons and field investigations will make the learning experiences richer and more meaningful for students. Students will be learning the skills of science as well as science content. The students will be actively engaged with the science they are learning and thus reach a deeper understanding of the content. Finally active engagement with science will likely lead students to become more interested and have more positive attitudes towards science.

RESOURCES

- A Key to Science Learning. Yockey, J. A. (2001). *Science & Children*, 38(7), 36-41.

  An article at the elementary school level, describing a simple writing technique to help students communicate the important science concepts they have learned.

- Centimeters, Millimeters, & Monsters. Goldston, J. M., Marlette, S., & Pennington, A. (2001). *Science & Children*, 39(2), 42-47.

  An article at the elementary school level, describing a humorous way to teach metric units.

- Drawing on Student Understanding. Stein, M., McNair, S., & Butcher, J. (2001). *Science & Children*, 38(4), 18-22.

  This article, at the elementary school level, describes how children can use drawings to communicate their understanding of animals. In the process, student learning about the animals is reinforced, as the children are encouraged to think deeply about what they know and have observed.

- *Learning and Assessing Science Process Skills*. Rezba, R. J., Sprague, C. S., Fiel, R. L., Funk, H. J., Okey, J. R., & Jaus, H. H. (3rd Ed.). (1995). Dubuque, IA: Kendall/Hunt Publishing Company.

A comprehensive text describing both the basic science process skills and the integrated science process skills in detail, along with suggestions of activities incorporating the skills with science content and appropriate assessment methods.

- Oh Say Can You See? Checkovich, B. H., & Sterling, D. R. (2001). *Science & Children*, 38(4), 32-35.

  An article at the elementary school level, describing a simple strategy for improving students' observation skills.

- *Teaching & Learning The Basic Science Skills: Videotape Series*. Rezba, R. J. (1999). Office of Elementary and Middle School Instructional Services, Virginia Department of Education, P.O. Box 2120, Richmond, VA 23218-2120. Call media office for copies of videotapes at 804-225-2980.

- When a Hypothesis is NOT an Educated Guess. Baxter, L. M., & Kurtz, M. J. (2001). *Science & Children*, 38(7), 18-20.

  An article at the elementary school level, discussing the difference between making a prediction (an educated guess about the outcome of a test) and forming a hypothesis (an educated guess about **why** the outcomes occurred).