TRB^3

Elementary Science Teacher Resource Book

A PROFESSIONAL DEVELOPMENT
RESOURCE FOR TEACHING
CORE CURRICULUM

GRADE 5

LITERACY -- STRATEGIES – ASSESSMENT

Utah State Office of Education

4. Fifth Grade Intended Learning Outcomes (ILOs)

Intended Learning Outcomes
for Fifth Grade Science

The Intended Learning Outcomes (ILOs) describe the skills and attitudes students should learn as a result of science instruction. They are an essential part of the Science Core Curriculum and provide teachers with a standard for evaluation of student learning in science. Instruction should include significant science experiences that lead to student understanding using the ILOs.

The main intent of science instruction in Utah is that students will value and use science as a process of obtaining knowledge based upon observable evidence.

- **Instruction should include significant science experiences that lead to student understandin g using ILOs**

By the end of fifth grade students will be able to:

1. **Use Science Process and Thinking Skills**
   a. Observable simple objects and patterns and report their observations.
   b. Sort and sequence data according to a given criterion.
   c. Given the appropriate instrument, measure length, temperature, volume, and mass in metric units as specified.
   d. Compare things, processes and events.
   e. Use classification systems.
   f. Plan and conduct simple experiments.
   g. Formulate simple research questions.
   h. Predict results of investigations based on prior data.
   i. Use data to construct a reasonable conclusion.
2. **Manifest Science Attitudes and Interests**
   a. Demonstrate a sense of curiosity about nature.
   b. Voluntarily read or look at books and other materials about science.
   c. Pose questions about objects, events, and processes.
   d. Maintain an open and questioning mind toward new ideas and alternative points of view.
   e. Seek and weigh evidence before drawing conclusions.
   f. Accept and use scientific evidence to help resolve ecological problems.
3. **Understanding Science Concepts and Principles**
   a. Know and explain science information specified for their grade level.
   b. Distinguish between examples and non-examples of concepts that have been taught.
   c. Solve problems appropriate to grade level by applying science principles and procedures.

4. **Communicate Effectively Using Science Language and Reasoning**
    a. Record data accurately when given the appropriate form (e.g., table, graph, chart).
    b. Describe or explain observations carefully and report with pictures, sentences, and models.
    c. Use scientific language in oral and written communication.
    d. Use reference sources to obtain information and cite the source.
    e. Use mathematical reasoning to communicate information.
5. **Demonstrate Awareness of Social and Historical Aspects of Science**
    a. Cite examples of how science affects life.
    b. Understand the cumulative nature of science knowledge.
6. **Understand the Nature of Science**
    a. Science is a way of knowing that is used by many people not just scientists.
    b. Understand that science investigations use a variety of methods and do not always use the same set of procedures; understand that there is not just one "scientific method."
    c. Science findings are based upon evidence.

- Instruction should include significant science experiences that lead to student understanding using ILOs.

DESCRIPTION OF THE INTENDED LEARNING OUTCOMES

Adapted from work by Richard Sudweeks, Department of Instructional Science
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THE PRIMARY GOAL

The primary goal of the science core curriculum is that "Students will value and use science as a process of obtaining knowledge based upon observable evidence." The purpose of the curriculum is not to make a scientist out of every student, but it is aimed at helping all students develop (1) science literacy and (2) positive attitudes about using science as a way of obtaining knowledge. Students are expected to learn how to *do* science, how to communicate the results of science inquiries to others, and how to use their knowledge of science concepts and principles to reason about science and to solve problems. The curriculum is also designed to help students at all grade levels better understand the nature of scientific knowledge and the process by which it is produced.

The primary goal is intended to be reached through the attainment of the sic categories of supporting goals described below. The statements in each of these categories are expressions of specific intended outcomes that students should achieve as a result of their experience in studying science. Together these six categories represent a broad range of educational goals including cognitive, affective, and behavioral outcomes. In affective domain, the specific intended outcomes include beliefs, attitudes, and interests. In the cognitive domain, the intended outcomes include higher-order thinking and reasoning skills as well as recall of factual knowledge that provides students with information with which to reason. The behavioral domain focuses on science process skills and abilities that enable students to conduct science investigations of their own.

THE SIX SUPPORTING GOALS

1. Students will use science process and thinking skills.
Science is an activity. It is something people *do*. It is an inquiry process that people use to learn about the world around them. This inquiry process includes effective use of the following skills: observing, measuring, classifying, predicting, and locating information in reference sources.

<u>Observing and Measuring</u>. Effective observers rely heavily on their sense of sight, but they complement their sight with use of their other senses. They look carefully, listen intently, and call upon their other senses as needed and appropriate to collect as much information as possible about the object or process being observed. Students need to be taught how to use magnifiers and other devices to aid and extend their ability to observe. In addition, they need to be taught how to use rulers, balances, thermometers, and other simple measuring devices as a means of making more precise descriptions.

Students need to be taught how to describe and record what they observe. An *observation* is a description or report of what was observed. Since such reports provide the evidence upon which further inquiry and reasoning are based, students should be taught to report observations as accurately and as free from interpretation and inference as possible. An investigation that begins with inaccurate or incomplete observations will likely lead to invalid conclusions.

<u>Sorting and Classifying</u>. Science is a search for meaning. Persons who *do* science do not just collect piles of observations; they attempt to organize their observations and make sense out of them based on recognizable patterns and observed similarities and differences. One way they do this is by grouping objects or events they observe into increasingly specific categories based on observable characteristics of the objects. This grouping or sorting activity requires sequencing data according to a given criteria.

Sorting and grouping activities should begin in kindergarten. Most kindergartners can readily learn to sort objects into categories defined for them by someone else. As students mature and become skillful in making finer discriminations, they should be taught to infer and use categories of their own based on the similarities and differences they observe in the objects. This is called classifying. They should learn that the same set of data can usually be classified in different ways depending on the categories used. The development and refinement of a workable classification framework is a primitive form of theorizing. Grade school students may not be ready to develop and evaluate theories per se, but they can readily be taught to develop and use their own classification schemes. This includes comparing things, processes and events.

<u>Predicting</u>. As students study patterns and relationship among observable events in nature, they begin to make predictions about events that are likely or unlikely to occur in other situations. Of course predictions of this kind are uncertain, but they are not just wild guesses or uninformed hunches. They are informed inferences based on evidence. They are also based on assumptions that the previously observed conditions are similar or dissimilar to the circumstances in the new situation in some specified way.

The reasoning and generalizing that lead to such predictions are part of the inquiry process because they lead to the formulation of testable hypotheses which define anticipated relationships among variables. Hence students should be encouraged to make such predictions and then seek to confirm or disconfirm them.

Teachers should also help students relate the process of making and checking predictions to their study of relevant concepts in the mathematics curriculum such as *certainty, uncertainty, more likely,* and *less likely.*

<u>Locating information in reference sources</u>. The ability to locate relevant information in almanacs, handbooks, encyclopedias, compact disks, computer databases, back issues of magazines and newspapers, and other reference sources is another important inquiry skill in which students need instruction. By the time they reach the fifth and sixth grades, students should have developed basic skills in locating such information.

The intended learning outcomes described in this category also include the inquiry skills students need to plan and conduct a formal study or science investigation on their own. The inquiry may be either a controlled experiment or an observational study. By fifth and sixth grade, students should begin to develop hypotheses to answer their questions. By sixth grade students should begin to consider variables in their experimentation. The following section on variables is included to assist teachers, not for student study.

A *variable* refers to any distinguishable characteristic or property that varies in amount or kind among the objects in a group. For example, students differ in terms of variables such as age, height, weight, gender, eye color, shyness, occupational interests, and science literacy. Each of these characteristics is a variable. Similarly, liquids differ in terms of variables such as temperature, color, saltiness (salinity), density, and boiling point. Planets in the solar system differ in terms of variables such as overall size, length of day, length of year, number of moons, etc.

The process of conceptualizing and defining variables that are likely to account for similarities, differences, patterns, and or relationships among groups of objects of events is an important part of science. A variable that is deliberately changed in a study by the researcher is called a *manipulated variable* (or *independent variable*). All experiments include at least one manipulated variable. For example, suppose a student conducted a simple experiment that involved placing different amounts of fertilizer on three different bean plants in order to observe the effect of varying the amount of fertilizer on the growth rate of the plants. The manipulated variable in this experiment would be the amount of fertilizer. The other variable, the growth rate of the bean plants, would be called the *response variable* (or *dependent variable*). Hence, the response variable is some other variable that may be changed as a result of the experimental manipulation.

In planning a research study, a researcher usually defines the focus of the proposed study he or she plans to conduct by defining a series of research questions or hypotheses to be investigated. A hypothesis is a declarative sentence which makes an assertion about how two or more variables are related. To be scientifically useful, such statements must be directly testable. This means that each variable must be clearly stated and observable, and the predicted relationship between them must be defined clearly enough that one can readily determine what counts as evidence in deciding whether or not the alleged relationship is true. A research question is an interrogative sentence which describes the unresolved problem or issue that a researcher plans to investigate. Research questions are typically used when the investigator has no basis for making an informed hypothesis about how the variables in a study are related. Students need to develop skill in formulating both well-defined hypotheses and research questions.

Measurement is often used in both experiments and field studies. For example, it would probably be necessary to measure the amount of fertilizer placed on the different beans in the example described above. It would also be necessary to find some way of measuring the growth rate of the plants. However, before a variable can be measured, it must be operationally defined. To operationally define a variable means to decide how to measure it. This process involves deciding what counts as evidence, what change has occurred and how to collect such evidence. Usually there is more than one way to operationally define a variable. For example, the growth rate of bean plants might be defined as centimeters per day or as inches per week, etc.

The final step in the inquiry process is to interpret the data or evidence collected in the study of the research questions or hypotheses on which the study focused. This interpretive process involves drawing defensible inferences about similarities, differences, and patterns among the objects and events observed, or about relationships between variables. The goal is to formulate plausible explanations and defensible predictions based on the observed data that apply to other unobserved, but similar situations or cases. Students have to be taught to avoid jumping to conclusions that are not warranted by the data. Teachers need to continually ask them questions such as:

1. "What evidence do you have to support that conclusion?"
2. "What other explanations or conclusions could also account for what you observed?"
3. "How do you know that one of these other explanations is not just as good or better than the Conclusion or explanation you have offered?"

2. Students will manifest scientific attitudes and interests

Like scientists, children are naturally curious. Children's propensity to explore and to ask questions is evidence of this curiosity. But children differ from scientists in that they lack knowledge of how to find answers to their questions and how to evaluate how good the answers are.

One important goal of science instruction is to enhance children's innate inquisitiveness and channel it in productive ways. Skillful teachers focus children's curiosity without squelching it. Science education should enhance children's sense of wonder and increase their desire to find out about phenomena they observe in nature. The insights children gain as they begin to understand and reason about events, processes, and relationships in nature should lead them to formulate more discerning questions and to desire to conduct more telling investigations as they search for credible answers.

Although most children are born with an ability to think, they have to learn how to think effectively. They have to be taught the thinking habits and attitudes that are associated with science. These include (1) open-mindedness, (2) the habit of seeking and weighing evidence before drawing conclusions about the validity of scientific claims, and (3) choosing to read and look at books and other materials about science to understand what others have learned.

Open-mindedness refers to an individual's receptiveness to new ideas and willingness to thoughtfully consider accepting points of view which differ from customary ways of thinking and believing. Closed-mindedness is the tendency to reject ideas which differ from one's own without considering their merits. Open-mindedness is highly valued in science, but so is the habit of asking questions. A thoughtful person does not accept new ideas before carefully examining them. This examination process involves formulating pertinent questions and actively seeking answers to them. The disposition to be open-minded and the habit of asking relevant questions may seem to be incompatible traits. But neither excludes or diminishes the other. Rather, the two traits complement and enhance each other.

Science depends upon the collection, evaluation, and interpretation of evidence. This characteristic distinguishes science from other ways of learning and knowing. The various scientific disciplines differ in numerous ways, but one characteristic they all have in common is this dependence on verifiable evidence as a means of assessing knowledge claims. One of the most important thinking habits a child can learn from grade school science is to routinely ask for the evidence that supports purported knowledge claims. This is simply the habit of routinely asking, "How do we know that's true?"

Science is not the only legitimate way of gaining knowledge. Many questions and issues in life cannot be settled by using the methods of science. The purpose of science education is not to make a scientist out of every student, but the experience of studying and doing science should help every student develop a healthy balance between openness and skepticism.

3. Students will understand science concepts and principles.
The objectives in this category describe cognitive skills, intellectual processes, and mental operations that students should learn to use and draw upon as needed. All literate persons in science should have a basic knowledge of terminology and factual information that they are able to draw upon as needed as they engage in thinking and reasoning about science-related issues and concerns. This means that it is important for students to know and explain information. This means that it is specified to the grade level.

Students who understand a principle should be able to explain it in their own words, or demonstrate natural phenomena which illustrate the principle. Problem solving is an especially important objective. The intent here is that students should be able to reason with their knowledge of science and apply it to previously encountered problem situations. Students should not always be given problems that are already structured and defined. Two important aspects of problem solving involve knowing how to define what the problem is and then deciding which solution is appropriate.

4. Students will communicate effectively using science language and reasoning.
Science literacy includes the ability to communicate scientific ideas and share information with clarity. Children in primary grades should be given many opportunities to tell others what they observed and to compare their observations with what other reported. Even in these early grades, children should learn that careful description is important. They should not be expected to provide accurate scientific explanations of what they observed, but they should learn to accurately report what they observed.

Students in the primary grades can learn to describe and compare objects in terms of number, size, shape, color, weight, and texture. If necessary, students can use pictures to describe what they have observed. By the time they reach the third grade, students should be skillful at making pictures. They should also be learning to use numerical data and describe and compare objects and events. Students in the fifth and sixth grades should be able to organize information in two-dimensional graphs and tables that portray relationships between variables. They should also be able to read and interpret simple two-dimensional graphs and tables prepared by others and to express in their own words the meaning of the information in these tables and graphs.

Students in grades 5 and 6 should also be able to actively participate in group discussions of issues in science by being able to express their own points of view, to summarize what others have said, and to ask for clarification or elaboration when needed.

The process of doing science includes preparing written and oral reports that (1) define the problem that was investigated, (2) describe the procedures used to collect observations, (3) present the principle findings of the study, and (4) explain the investigators conclusions based on findings. At least by the second grade, students can learn how to prepare such reports in a simplified form. By the time they reach the fifth and sixth grades, students should be capable of preparing such reports in greater detail and with less assistance. Students only learn to write by writing, and they only learn to prepare and present oral reports by doing so. There is no substitute for experience in this regard.

Students at all levels should be expected to use the language of science to express the concepts and relationships taught in the science core curriculum at their level. However, the science core curriculum should not be presented as a series of vocabulary lessons. Nor should students' knowledge be assessed merely in terms of their performance on a vocabulary test. What is most important is that students understand the ideas behind the terminology and be able to reason with these ideas and use them in *doing* science. The terms are simply labels and conventions that facilitate communication. Such terms should be transparent to the students in the sense that students should be able to see through the terms to the ideas they represent. Hence, as much as possible students should be given direct experience in using the ideas and concepts they are expected to learn.

5. Students will demonstrate awareness of social and historical aspects of science.
Science is a human activity. And since scientists are humans, they are not all the same. They vary from person to person just like other people, and they share the same kinds of frailties and idiosyncrasies that other humans tend to have. The goals and aspirations that motivate scientists are very similar to those that motivate humans in other fields of endeavor. Students need to appreciate the humanness of scientists and the kinds of challenges, struggles, and tragedies that different scientists have experienced in trying to get their ideas accepted.

Scientific inquiry does not occur in a vacuum. It takes place in a social, historical, and cultural context like all other human activities. Students need to understand how social and cultural factors have impeded the development of science in some situations and how they have facilitated its development in other situations.

Case studies of particular scientific discoveries and historical episodes are useful means of helping students broaden their understanding of how science works in practice. The history of science shows that the way science is actually conducted differs from the stereotypic view that is often presented by science textbooks.

Biographies of scientists and historical anecdotes are a useful means of helping students to better appreciate the contributions of individual scientists and the challenges they faced. Biographies can also help students gain a feeling for the alternation of excitement, elation, and disappointment that accompany the work of scientists. The historical incidents selected should include examples of the work of female scientists. These examples should also illuminate the need for creativity and imagination in research as well as the important role improvisation in scientific accomplishments.

Teachers sometimes try to infuse a historical approach into their teaching by simply describing to their students the results or conclusions of a particular scientist's work. This approach is a mistake. Students need detailed descriptions of the process the researcher followed and the context in which he or she worked so that they gain an understanding of the many false starts and dead-ends the scientists encountered. They need to know the evidence the scientist had at hand the reasoning used to arrive at the conclusions reached, and what plausible alternatives were considered and rejected.

It is also helpful for students to see that accepted conclusions in science have changed over time, and to understand the factors that led to the discarding of old views and the acceptance of newer perspectives. Historical literacy is part of being scientifically literate which in turn is part of being culturally literate. Students in grades 5 and 6 should especially benefit from exposure to case studies, biographies, and anecdotes that reveal science as it has been practiced historically.

Teachers should also help students understand the role that science plays in society and civilization at large. If students are to accept responsibility for helping to resolve social, ethical, and ecological problems related to science and technology, they need to be helped to understand that the actions of each individual in society matters and that his/her personal efforts can make a difference.

6. Students will understand the nature of science.
Understanding the nature of science includes an understanding of (1) how the process of science works, (2) the nature of scientific knowledge, and (3) the attitudes, values, and habits of mind associated with this inquiry process and the resulting knowledge. Scientifically literate individuals understand the relationships among these three aspects of science and how they complement each other.

The process of science is a dynamic activity that includes systematic means of collecting observations and measurements, formulating tentative explanations and testing these hypotheses in light of the observable evidence, and drawing conclusions based on the results. This process is generally cyclical and on-going because the evidence collected from any single inquiry usually does not provide defensible answers to all of the relevant questions or issues.

It is an oversimplification to assume that there is one scientific method that is common to all science. There is no single, fixed set of steps that all scientists follow in conducting their work. However, the different fields and disciplines of science do have much in common. They all rely upon observable evidence, the formulation and testing of hypotheses, and similar forms of reasoning. And they all have a similar goal: to produce credible explanations of natural phenomena that can be validated by further investigation. The essence of science consists of formulating credible predictions and explanations and validating them by observation.

However, it is not sufficient for scientific theories to simply account for the evidence at hand. Theories should be generalizable. That is, a good theory should also explain other similar observations that were not used in the formulation of the theory. This additional evidence might consist of historical data that has not yet been studied, data from other contemporary sources, or data from events yet to take place in the future. To the extent that a theory is generalizable, it possesses predictive power. One purpose of science is to explain; another purpose is to predict.

Science values objectivity in collecting observations. But objectivity is a matter of degree. What an observer sees is always influenced to some extent by the conceptual framework or point of view the observer brings to the situation. Hence, observations are never completely objective in an absolute sense and what the observer reports as statements of fact are interpretations influenced by the lens of the observer's previous experience and the concepts he or she takes for granted.

Since science is an inductive process, knowledge claims that results from scientific inquiries should always be considered incomplete, tentative, and subject to being modified or discarded as new evidence is collected or as new reasoning is employed. Some hypotheses and theories may be better confirmed than others, but confirmation is always relative. The idea that knowledge can ever be proven absolute by sciences is a myth and reflects an incorrect understanding of the nature of science. The history of science contains numerous examples of how explanations that were once accepted as "scientific truth" have either been revised and improved or completely discarded and replaced.

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