What Research Says about Science Process Skill?

Dr. C V Satyaprakasha ¹, Kalyani K ²
¹Associate Professor
Department of Post Graduate Studies in Education
Vijaya Teachers College, Bangalore-11.
²Assistant Professor
Department of Post Graduate Studies in Education
Vijaya Teachers College, Bangalore-11.

Abstract
Science process skills are the indispensable tools of scientists, helping them form their conceptual framework, thereby facilitating learning of new content associated with novel science problems. Through explicit instruction and assessment of students’ science process skills teachers can help students gain the same skills that faculty use every day and help them to approach science as scientists do. Acquisition of science process skills can have a profound impact on student success in school science classes. Although content is clearly important, science process skills provide the tools and ways of thinking that enable students to build the robust conceptual frameworks needed to gain expertise in the life sciences. Scientists use these process skills to approach inquiry in a particular way, leading to a scientifically valid method for obtaining results from which they base new investigations. This paper focuses on types of science process skills and what research says about process skill.

Keywords: Science Process Skills, Conceptual Frameworks, Scientific Thinking, Critical Thinking, Effectively Integrated Information, Content Acquisition, Scientists

Introduction
Successful science school programs in the life sciences are those programs that students who are able to “think like a scientist” that is, students who are able to solve problems in multiple contexts and effectively integrate information into meaningful scientific concepts. Scientists and science educators agree that a hallmark of successful science learning is the acquisition of skills such as data interpretation, problem solving, experimental design, scientific writing, oral communication, critical analysis of primary literature, collaborative work, and monitoring and regulating one's own learning process. Although scientists use these skills daily, these skills are rarely taught to undergraduates in an explicit and scaffold manner. A more effective way to help students master science disciplines and better prepare them for careers in science would be through explicit instruction of science process skills, helping students acquire a repertoire of these skills early in the college curriculum and thereby augmenting their content acquisition and interdisciplinary ways of knowing.
Science process skills are the indispensable tools of scientists, helping them form their conceptual framework, thereby facilitating learning of new content associated with novel science problems through explicit instruction and assessment of students’ science process skills teachers can help students gain the same skills that faculty use every day and help them to approach science as scientists do. Indeed, these are the same skills strongly promoted by the American Association for the Advancement of Science (AAAS) for K–12 science education and highlighted in reports that outline recommendations.

Acquisition of science process skills can have a profound impact on student success in school science classes. Although content is clearly important, science process skills provide the tools and ways of thinking that enable students to build the robust conceptual frameworks needed to gain expertise in the life sciences. Scientists use these process skills to approach inquiry in a particular way, leading to a scientifically valid method for obtaining results from which they base new investigations. American Association for the Advancement of Science (AAAS) identified thirteen science processes. These are best thought of as a set of intellectual skills that are associated with acquiring reliable information about nature. Each process is defined. In addition, comment about the inherent nature of each of the skills is provided. The first eight processes are called "basic processes" and are appropriate for children in the primary grades. The last five are called integrated processes and are more appropriate for children at grades four and above. In the present study observation, inference, generalization, generalization and prediction were the process skills selected for testing its development due to the implementation of multi media teaching.

The purpose of science education is to enable individuals to use scientific process skills; in other words, to be able to define the problems around them, to observe, to analyze, to hypothesize, to experiment, to conclude, to generalize, and to apply the information they have with the necessary skills. Scientific process skills (SPS) include skills that every individual could use in each step of his/her daily life by being scientifically literate and increasing the quality and standard of life by comprehending the nature of science. Therefore, these skills affect the personal, social, and global life’s of individuals. The SPS are a necessary tool to produce and use scientific information, to perform scientific research, and to solve problems. These skills can be gained by students through certain science education activities (Harlen, 1999; Huppert, Lomask and Lazarorcitz, 2002). For example, the purpose of learning by using a research study is to help teach the scientific processes. The students undertaking a scientific research study can learn the processes of science (Dhillon, 1996).

The following is a list of the science processes advocated by the American Association for the Advancement of Science (AAAS). These are best thought of as a set of intellectual skills that are associated with acquiring reliable information about nature. Each process is defined. In addition, comment about the inherent nature of each of the skills is provided. The first eight processes are called "basic processes" and are appropriate for children in the primary grades. The last five are called "integrated processes" and are more appropriate for children at grades four and above.

3 What the Research Says About Science Process Skills?

One of the most important and pervasive goals of schooling is to teach students to think. All school subjects should share in accomplishing this overall goal. Science contributes its unique skills, with its emphasis on hypothesizing, manipulating the physical world and reasoning from data.
The scientific method, scientific thinking and critical thinking have been terms used at various times to describe these science skills. Today the term "science process skills" is commonly used. Popularized by the curriculum project, Science - A Process Approach (SAPA), these skills are defined as a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behavior of scientists. SAPA grouped process skills into two types-basic and integrated. The basic (simpler) process skills provide a foundation for learning the integrated (more complex) skills. These skills are listed and described below.

Scientists engage in procedures of investigation to gain knowledge of natural phenomena. These tactics and strategies, the skills scientists use in their pursuit of understanding, are summarized below:

4 Basic Science Process Skills

4.1 Observation
Science begins with observations of objects and events. These observations lead to the asking of questions. Crucial to the method of science is the ability to ask the right question and to make selected observations relevant to that question. Observations are influenced by past experience, often involve instruments and require careful recording and description. Surprising or unexpected observations occasionally contribute new and important knowledge.

4.2 Measurement
Measurement involves assigning numbers to objects or events that may be arranged in a continuum according to a set of values. Expression of observations in quantitative terms adds precision and permits more accurate description.

4.3 Experimentation
An experiment is a series of observations carried out under special conditions. The distinction between observation and experimentation is slight. An experiment always consists of observations, but it is more than that because the observers usually interfere to some extent with nature. Experimentation is the hallmark of good science whether it comes at the beginning as a gathering of facts or at the end in the final test of a hypothesis.

4.4 Communication
A scientist is obligated to make the information from observation and experimentation available to the scientific community for independent confirmation and testing. Discussion and critical analysis of findings are the key means by which science advances. Scientists disseminate their results in journals, at professional meetings, seminars, and through informal networks. This dissemination contributes to the common core of knowledge of the past and provides the vehicle for continuous review of this body of knowledge. Communication is the means by which purpose and usefulness are given to scientific investigation.

4.5 Critical Thinking Skills
Although the boundaries are hazy, it appears that certain thought processes are part of the common pattern of scientific investigation. These include inductive reasoning, formulation of hypotheses, deductive reasoning, and a variety of mental skills such as analogy, extrapolation, synthesis, and evaluation. In addition to these traditional processes, scientific inquiry abounds with approaches described variously as speculation, guess, intuition, hunches, or insight. The exact mechanisms by which these processes function are unknown but they are commonly cited in the autobiographies of the great scientists.
5 Learning Basic Process Skills

Numerous research projects have focused on the teaching and acquisition of basic process skills. Padilla, Cronin, and Twiest (1985) surveyed the basic process skills of 700 middle school students with no special process skill training. They found that only 10% of the students scored above 90% correct, even at the eighth grade level. Several researchers have found that teaching increases levels of skill performance. Thiel and George (1976) investigated predicting among third and fifth graders, and Tomera (1974) observing among seventh graders. From these studies it can be concluded that basic skills can be taught and that when learned, readily transferred to new situations (Tomera, 1974). Teaching strategies which proved effective were: (1) applying a set of specific clues for predicting, (2) using activities and pencil and paper simulations to teach graphing, and (3) using a combination of explaining, practice with objects, discussions and feedback with observing. In other words—just what research and theory has always defined as good teaching.

5.1 Integrated Science Process Skills
1. Formulating Hypotheses – it means stating the proposed solutions or expected outcomes for experiments. These proposed solutions to a problem must be testable.
2. Identifying of Variables – It refers for stating the changeable factors that can affect an experiment. It is important to change only the variable being tested and keep the rest constant. The one being manipulated is the independent variable; the one being measured to determine its response is the dependent variable; and all being kept constant are constants or controlled variables.
3. Defining Variables Operationally – It refers to the explanation of how to measure a variable in an experiment.
4. Describing Relationships Between Variables – It means explanation of relationships between variables in an experiment such as between the independent and dependant variables.
5. Designing Investigations – It refers to designing of an experiment by identifying materials and describing appropriate steps in a procedure to test a hypothesis.
6. Experimenting - carrying out an experiment by carefully following directions of the procedure so the results can be verified by repeating the procedure several times.
7. Acquiring Data – It refers to the collection of qualitative and quantitative data as observations and measurements.
8. Organizing Data in Tables and Graphs – It refers to the preparation of data tables and graphs for data collected.
9. Analyzing Investigations and Their Data - It includes interpretation of data, identification of errors, evaluation the hypothesis, formulation conclusions, and recommendation further testing where necessary.
11. Formulating Models - It includes recognizing patterns in data and making comparisons to familiar objects or ideas.

5.2 Learning Integrated Process Skills
Several studies have investigated the learning of integrated science process skills. Allen (1973) found that third graders can identify variables if the context is simple enough. Both Quinn and George (1975) and Wright (1981) found that students can be taught to formulate hypotheses and that this ability is retained over time.
Reading and activity-oriented science emphasizes the same intellectual skills and are both concerned with thinking processes. When a teacher helps students develop scientific processes, reading processes are simultaneously being developed. The research on strategies and methodologies for teaching science in elementary schools has produced clear evidence that students in process-approach programs learn more than do students in traditional textbook-based programs (Bredderman, 1983).

The research indicates that the process-approach programs of the sixties and seventies, Elementary Science Study (ESS), Science Curriculum Improvement Study (SCIS), and Science-A Process Approach (SAPA), were more effective in raising student performance and attitudes than the traditional reading-based programs. Data from meta-analyses by Shymansky et al. (1983) on student performance across these activity-based programs, in terms of performance clusters and a composite performance measure show that students in the hands-on programs outperformed their traditional elementary school counterparts by 9 percentile points.

6 Science Process Skills and Other Disciplines

How can Teaching Science Process Skills Improve Student Performance in Reading, Language Arts, and Mathematics?

The science process skills are part of and central to other disciplines. Research indicates that the integration of science with reading and mathematics has produced positive effects on student learning:

6.1 Science Process Skills and Language

6.1.1 The Relationship Between Reading and Science Process Skills

Research indicates that a strong experienced-based science program, one in which students directly manipulate materials, can facilitate the development of language arts skills (Wellman, 1978). Reading and activity-oriented science emphasizes the same intellectual skills and are both concerned with thinking processes. When a teacher helps students develop science process skills, reading processes are simultaneously being developed (Mechling and Oliver, 1983 and Simon and Zimmerman, 1980). The hands-on manipulative experiences science provides are the key to the relationship between process skills in both science and reading (Lucas and Burlando, 1975).

Children's involvement with process skills enables them to recognize more easily the contextual and structural clues in attacking new words and better equips them to interpret data in a paragraph. Science process skills are essential to logical thinking, as well as to forming the basic skills for learning to read (Barufaldi and Swift, 1977).

6.1.2 Teaching Science Process Skills Enhances Reading Readiness

Guszak defines reading readiness as a skill-complex. Of the three areas within the skill-complex, two can be directly enhanced by science process skills: (1) physical factors (health, auditory, visual, speech, and motor); and (2) understanding factors (concepts, processes). When students see, hear, and talk about science experiences, their understanding, perception, and comprehension of concepts and processes may improve (Barufaldi and Swift, 1977 and Bethel, 1974). Evidence suggests that early experiences in science help children of all socioeconomic levels in language and logic development (Thelen, 1976).
Science activities provide opportunities for manipulating large quantities of multisensory materials which promotes perceptual skills, i.e., tactile, kinesthetic, auditory, and visual (Neuman, 1969). These skills then contribute to the development of the concepts, vocabulary, and oral language skills (listening and speaking) necessary for learning to read (Wellman, 1978).

Science programs that emphasize hands-on manipulative experiences, enhance the development of process skills in young children. The attainment of process skills developed by such science experiences are positively correlated with the development of reading readiness (Nicodemus, 1968; Ritz, 1969; Rowe, 1968; and Stafford, 1969).

6.1.2 (a) Teaching Science Process Skills Enhances Reading Skills in the Intermediate and Upper Elementary Grades

Studies viewed cumulatively suggested that science instruction at the intermediate and upper elementary grades does improve the attainment of reading skills. The findings reveal that students have derived benefits in the areas of vocabulary enrichment, increased verbal fluency, enhanced ability to think logically, and improved concept formation and communication skills (Campbell, 1972; Kraft, 1961; Olson, 1971; Quinn and Kessler, 1976).

6.1.2 (b) Teaching Science Process Skills Enhances Oral and Written Communication Skills

As with all process skills, only through actual practice does competence in oral and written communication develop. Involvement in activity-based science programs provides learners with a multitude of experiences to draw from when they think and write (Simon and Zimmerman, 1980). A study of the relationship between creative writing and science experiences indicates that when children write their own reading materials, their writing scores improve significantly (Jenkins, 1981). Work with children from inner-city schools found significant gains in children's oral communication skills when they participated in Science Curriculum Improvement Study and Science-A Process Approach activities. Children who were exposed to Science- A Process Approach out-performed students who were not in tests of language output, vocabulary, sentence structure, and classifying, transmitting, and receiving oral communication skills. (Bethel, 1974 and Huff and Languis, 1973).

6.2 The Relationship Between Science Process Skills and Mathematics

Science and mathematics are integrally related. Mathematics, to a great extent, is the language of science. The development of skills in logical mathematical reasoning and problem-solving is a goal of both science and mathematics instruction (National Council of Teachers of Mathematics, 1980 and National Science Teachers Association, 1964 and 1983). Science and mathematics reinforce each other, thereby facilitating better cognitive development (Almy, 1966).

6.2.1 Teaching Science Process Skills Enhances Achievement in Mathematics

Research has demonstrated that a variety of science experiences can facilitate the transition of students from one level of cognitive development to the next. A relationship between science and mathematics is suggested by the fact that one's achievement in mathematics is related to one's level of cognitive development (Almy, 1966; Ayes and Ayers, 1973; Ayers and Mason; Froit, 1976; Renner, 1971; and Stafford and Renner, 1976).

Involving students in "hands-on" activities, where they count and manipulate objects, provides experiences that contribute to their understanding of number. In addition, science experiences contribute to the development of other operations basic to the study of mathematics. Some of these operations are: conserving substance and length, one-to-one correspondence, ordering, seriating, and classifying (Campbell, 1972).

The contribution of science experiences to the development of operations basic to the study of mathematics is substantiated by research. In studying the relationship between students' ability to
conserve number and quantity and mathematical performance, it was found that students having the ability to conserve experience greater success in learning mathematical skills and concepts. Students who had mathematics-science programs performed better on conservation and transitivity tasks than did those who received only mathematics instruction (Almy, 1966).

Research further indicates that science experiences not only enhance the operational abilities of kindergarten and first grade students, but also facilitate the transition from one level of cognitive development to the next among older students (Froit, 1976 and Tipps, 1982).

6.2.2 Teaching Science Process Skills Enhances Problem-Solving Skills in Mathematics

Research has shown that science can be used to broaden the current approach to teaching problem solving in mathematics. Replacing contrived problems with real-world science problems has the potential to enhance the problem-solving abilities of students, while promoting a greater appreciation of the usefulness of problem solving in a multitude of circumstances (Coffia, 1971 and Shann, 1977). Through science experiences, students can apply mathematics to real-world problems. At the elementary level, the teacher can provide hands-on science activities that facilitate the learning of abstract arithmetic concepts such as number sequencing, regrouping, and fractions (Mechling and Oliver, 1983).

7 Summary and Educational Implications

The concepts, processes, and methods found in science are used in other disciplines. Many science-class activities are predicated on students' reading and writing skills. Students read textbooks, read directions for conducting experiments, and write their own reports of observation. Science's integration with mathematics also requires little effort since the development of logical mathematical reasoning and problem-solving skills is a goal of instruction in both disciplines.

A reasonable portion of the science curriculum should emphasize science process skills according to the National Science Teachers Association. In general, the research literature indicates that when science process skills are a specific planned outcome of a science program, those skills can be learned by students. This was true with the SAPA and SCIS and other process skill studies cited in this review as well as with many other studies not cited. Teachers need to select curricula which emphasize science process skills. In addition they need to capitalize on opportunities in the activities normally done in the classroom. While not an easy solution to implement, it remains the best available at this time because of the lack of emphasis of process skills in most commercial materials.

8 References


