

Historical Development of Teaching Science as Inquiry

2

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Over the past 200 years, science teaching in the United States has evolved from conveying science as a body of knowledge to a more learner-centered approach, generally referred to as teaching science as inquiry. This latter approach challenges students to form deep understandings about natural phenomena by engaging in the construction of scientific knowledge through an active process of investigation.

Secondary school science teaching today should be initiated by focusing on scientific theories and models, asking researchable questions, generating hypotheses, gathering information, presenting evidence, and forming arguments—that is, by thinking, investigating, and talking science. This approach can be supported and complemented when students hone their investigative skills and teachers stress the applications of science and discuss the history and nature of science.

This chapter examines four periods in the history of science education. In particular it looks at how societal pressures brought about the teaching of science as inquiry in each period and how educators, cognitive psychologists, and scientists have responded with recommendations appearing in national

science education reform documents. In addition, this review looks at the influence of scientists on the content and process of scientific inquiry and the contribution of cognitive psychologists to student-centered learning.

The Emergence of Teaching Science as Inquiry

The Period From the Early 1800s to 1915

During the early 1800s the United States was building a nation. Cities were small and most people lived in rural areas. Secondary schools were in their infancy, attended only by the privileged in preparation for college. The few science courses offered in high schools stressed the practical sides of science and technology, such as astronomical calculations, navigation, mensuration (measurement), and surveying. After 1860 many high school curricula included botany, meteorology, mineralogy, physiology, and zoology. Science courses in the mid- to late 1800s were descriptive and included little or no laboratory work. Many individuals who were teaching science lacked a strong background in science. Didactic instruction was the teaching standard, and science was taught primarily as a body of factual information.

At this time, college science programs, because of college entrance requirements, directly influenced high school biology, chemistry, and physics courses. High school science teaching began to emulate college and university instruction, with little attention paid to students' interests or the need to understand the environment. High school science courses became watered-down college science courses in which teachers covered many textbook chapters, implementing a laboratory exercise now and then. These courses stressed science as content, with little attention given to investigation or technology; they rarely reflected on how scientific work is conducted. Late in the 19th century, however, national committees recognized the domination of high school science by college science teaching and sought to change the situation.

The Committee of Ten (Committee on Secondary School Studies 1893) proposed to standardize the high school curriculum. In a report, the committee asserted that secondary schools did not exist for the sole purpose of educating our youth for college. The report also recommended a better alignment of programs from elementary through high school. The report had the effect of decreasing the influence of colleges on some high school science courses. However, even with more science courses offered in the secondary

school—some for the college-bound students and some for those not college bound—students were still not learning science through investigation.

Two trends in high school science emerged during the late 1800s and early 1900s. One was an emphasis on having students learn the applications they would need to function in an industrial society. The other trend stressed preparation for college science, which, as we know, was content heavy and didactic. In 1915, the Central Association of Science and Mathematics Teachers, convening on the national level, stressed that students should be taught the methods for obtaining accurate information.

The Period From 1915 to 1955

During the first half of the 20th century, many significant events—for example, World War I, the influenza pandemic, the Great Depression, and World War II—brought about political and social pressures that shaped the goals of public school education. School science programs stressed the practical aspect of science so that students could take their place as productive members of society. Although teaching science continued to emphasize factual information with some practical application, the process of science and the term *inquiry* began to appear in national committee recommendations and the research literature.

From about 1910 to 1930 the student population grew rapidly in the United States, as did the establishment of the grades 1–6, 7–9, 10–12 pattern of school organization. This situation brought about curriculum innovation and a broadening of the aims of science education, which were noted in the following general goal statements from the Commission on the Reorganization of Secondary Education (1918): (1) health, (2) command of fundamental process, (3) worthy home membership, (4) vocation, (5) citizenship, (6) worthy use of leisure time, and (7) ethical character. A report on secondary school science issued in 1920 reinforced these aims by encouraging science educators to incorporate them into science teaching, especially in general science and biology (Caldwell 1920).

However, a 1924 report from the Committee on the Place of Science in Education of the American Association for the Advancement of Science emphasized the importance of scientific thinking as a goal of science teaching; the report urged moving science instruction toward an inquiry-based approach (Caldwell 1924). The report stressed the importance of observation and experimentation, with the intent of giving students a better feeling for the scientific enterprise. In effect the scientific community was saying to educators that school science

needed to be more than teaching about the content of science; it also had to be about science as a way of thinking and investigating. This was a significant addition to the existing lists of science education goals.

Then in 1934 the Commission on Secondary Curriculum of the Progressive Education Association issued a report stressing the importance of reflective thinking in science, of focusing the curriculum on content that would be useful in students' lives, and of correlating life's problems with the curriculum (Progressive Education Association 1938).

One individual who had a great deal to say about the functional aspect of knowledge, scientific inquiry, and problem solving was John Dewey (1859–1952)—a philosopher, psychologist, and education reformer who held a pragmatic view of education. Dewey (1938), a leader of the progressive movement, stressed learning by doing and was opposed to learning simply for the sake of gaining knowledge. He was a proponent of learning the process of inquiry and of solving problems that were important to society and relevant to students.

Dewey believed that the development of the individual and the betterment of society should be the aims of education. He also believed that students should learn and use the scientific method rather than merely learn the core concepts of science. Scientific knowledge and especially “the method of science” were tools to enrich the lives of students.

Despite various recommendations from national committees to incorporate student inquiry into the science curriculum during the first half of the 20th century, few of the recommendations were ever implemented widely in science classrooms throughout the United States (Bybee 1977).

The Period From 1955 to 1980

The United States entered into a new era after World War II. During the 1950s and 1960s, the nation shifted from a war economy to a period of economic expansion and population growth, with many soldiers returning to civilian life, starting families, and raising children. The need for housing, schools, and transportation increased greatly. At the same time, the United States entered into a long Cold War with the Soviet Union, a situation that demanded military preparedness as well as scientific and technological advancement.

In the early to mid-1950s critics voiced concern about the state of public education. Mathematicians and scientists were especially critical, noting that students were not going into mathematics and science and that their high school

courses were out of date and out of line with those two disciplines. “The courses, [mathematicians and scientists] claimed, lacked rigor, were dogmatically taught, were content oriented, lacked conceptual unity, were outdated, and had little bearing on what was happening in the scientific disciplines” (Collette and Chiappetta 1989, pp. 11–12). University mathematicians and scientists found that students entering college were poorly prepared to study their subjects.

Although science and mathematics curriculum reforms were under way by the mid-1950s, the launching of the first space satellite, *Sputnik*, in 1957 by the Russians incited a massive curriculum reform program in U.S. science and mathematics education. The space satellite signaled that the Soviet Union was more advanced in science and technology than the United States, supporting earlier warnings that the U.S. education system was falling behind. The reforms brought about many changes and innovations in K–12 science curriculum materials; curriculum specialists, teachers, scientists, and mathematicians all played a role in these reforms.

One such reformer was Joseph Schwab (1909–1988), a contributor to the innovative Biological Sciences Curriculum Study (BSCS) high school biology course materials, who advanced our understanding of inquiry-based instruction. He enrolled in the university at age 15, earning undergraduate degrees in English and physics and later a doctorate in genetics (Westbury and Wilkof 1978). Schwab worked at the University of Chicago for over 50 years, where John Dewey had set up the Lab School and where educator Ralph Tyler (1902–1994) became well-known for his work in curriculum development.

The phrase “teaching science as enquiry” is conspicuous in a 1962 lecture by Schwab at Harvard University titled “The Teaching of Science as Enquiry.” Schwab preferred the use of *enquiry* to *inquiry*, because he disagreed with the ideas surrounding inquiry then being promoted, especially by psychologists. His idea of enquiry instruction was to teach students about the major paradigms of science, that is, the manner in which a certain community of scientists view a major idea and the way they investigate it. In his lecture, Schwab urged science educators to stress the conceptions of science and how they change over time. He placed a premium on how scientists view the ideas (content) they are developing and how these ideas shape what scientists do and say about the data they collect. Science should not be viewed as dogma, he said, but as revisionary and fluid. Teachers misrepresent science when they present it as a rhetoric of conclusion or as a finished product. He urged that students be active in the laboratory and that they develop their critical think-

ing skills by analyzing the works and original papers of scientists.

Around the same time, learning psychologist David Ausubel (1918–)(1963) advocated meaningful verbal learning, saying that science subject matter should be presented in a manner accessible to students. Learners, he said, will incorporate meaningful content into their knowledge bases, while they will quickly forget information learned by rote. Learning, Ausubel stressed, must begin with what the student knows, an assertion also made by today's constructivists and cognitive psychologists.

Jerome Bruner (1915–) (1961), on the other hand, was a staunch advocate of “learning by discovery.” He believed that the main purpose of education was to teach students how to learn rather than to simply accumulate information. Bruner held that there were four benefits of discovery learning: the increase of intellectual potency, the shift from extrinsic to intrinsic rewards, the heuristics of discovery, and the aid to the memory process. Bruner believed that by not feeding students explanations, teachers would encourage students to figure things out for themselves. Bruner's writings were used to promote the discovery and process approaches to science teaching.

Another major contributor to the evolution of science teaching was Jean Piaget (1896–1980), the most well-known developmental psychologist of his time. According to Piaget, intellectual development occurs through the construction of thinking skills (logical structures) that develop through experiences that challenge the learner to figure out puzzling events. Piaget's so-called concrete operational abilities (e.g., ordering, classifying, using numbers, and conserving mass) and formal operational abilities (e.g., combinatorial reasoning, proportional reasoning, controlling variables, and hypothetical reasoning) corresponded well with the science process skills that were the emphasis of the science process movement of the 1960s and 1970s.

It should be noted that not all science educators advocated the learning methods of inquiry science, largely because these methods lacked an emphasis on content. During the 1970s, Driver and Easley (1978) cautioned science educators not to give too much attention to learners' logical structures of thought and the data-gathering process involved in scientific investigation; they recommended giving more attention to conceptual frameworks of substantive knowledge. These researchers stressed the importance of getting students to think about and discuss their own ideas of phenomena and the importance of focusing on students' misconceptions and preconceptions.

The period from 1955 to 1980 was the golden era of science curriculum

reform in the United States, supported by large government funding in response to the scientific ascendancy of the Soviet Union. Government-sponsored textbook programs for high school science contained more up-to-date science content than did commercial textbooks. Further, textbooks that came out of those programs promoted inquiry-based instruction. Many papers, articles, and books of the time stressed the importance of involving students in learning how to do science.

As the result of Joseph Schwab's writings and curriculum work, teaching science as inquiry became a popular approach in the science education community. Inquiry science was promoted in high school, with an emphasis on work in the laboratory, in the belief that this strategy would teach students about the processes of science at the same time that it advanced their content knowledge. Unfortunately, the reform efforts did not reach all high schools in the country and the reform movement was not sustained by government funding. In addition, student achievement and interest in science was on the decline.

The Period From 1980 to 2006

During the 1980s, science education again came under criticism for not preparing youth to take their place in a scientific and technological society. Japan was becoming a formidable competitor in the world economy, particularly in the manufacture of automobiles, electronic equipment, and steel. Again, the United States felt threatened by another country, and the education system was called on to become part of the solution. This time it was an economic threat, which called forth a report titled *A Nation at Risk* from the National Commission on Excellence in Education (1983): "Our education system has fallen behind and this is reflected in our leadership in commerce, industry, science and technological innovations, which is being taken over by competitors throughout the world" (p. 5). As a result, many other reports were issued on the state of education, some of which were funded by the National Science Foundation.

A document by Project Synthesis summarized thousands of pages of reports from professional organizations on the state of science education (Harms and Yager 1981). The report recommended four goal clusters for science education: personal needs, societal issues, academic preparation, and career education. This orientation stressed the needs of students and the relationship among science, technology, and society, thus creating a better balance of science education goals than those that placed a heavy emphasis on pure science. The core content areas of science and teaching science as inquiry would take

a lesser role in science education, especially at the middle school level. In the late 1970s and during the 1980s, an attempt was made to take up a progressive movement in science education that saw social issues and values education as important goals (DeBoer 2000).

During the 1990s two reports appeared that set out to reform science education throughout the nation, with the intent of reaching all students in grades K–12. The first was *Science for All Americans: Project 2061* (AAAS 1990) and the second was *National Science Education Standards* (NRC 1996).

The goal of Project 2061 was to produce a scientifically literate society by the year 2061. Its mottos were “science for all students” and “less is more.” The document stressed student understanding of the nature of science, mathematics, and technology and how these enterprises function separately and together. Students should gain not only an understanding of the core concepts of the disciplines but also historical and contemporary perspectives of them. Leaders of the project sought to develop students’ curiosity and inclination to find out. However, the committee made no attempt to prescribe ways in which students should be taught science because there are many approaches to effective science instruction. Therefore, the translation of the Project 2061 goals were taken up by another group that produced national standards and called attention to the importance of inquiry in the science classroom.

The National Science Education Standards (NSES) (NRC 1996) gave high priority to inquiry-based science teaching, using the phrase “teaching science as inquiry” throughout. The importance of inquiry in the NSES is stated as follows:

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the

results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. . . .

Although the Standards emphasize inquiry, this should not be interpreted as recommending a single approach to science teaching. Teachers should use different strategies to develop the knowledge, understanding, and abilities described in the content standards. Conducting hands-on science activities does not guarantee inquiry, nor is reading about science incompatible with inquiry. . . .
(NRC 1996, p. 23)

A companion volume to the NSES, published in 2000, was *Inquiry and the National Science Education Standards* (NRC 2000). It provides teachers with many examples of inquiry-based instruction in many settings, from the classroom to the school grounds and into the community. In the foreword, Bruce Alberts, president of the National Academy of Sciences, wrote, “Students need to learn the principles and concepts of science, acquire the reasoning and procedural skills of scientists, and understand the nature of science as a particular form of human endeavor” (NRC 2000, p. xiii). *Inquiring Into Inquiry Learning and Teaching in Science* (Minstrell and van Zee 2000) similarly informed educators about inquiry-based science instruction.

The field of cognitive psychology has grown significantly since the 1980s, providing educators with important insights into teaching and learning science (e.g., Bransford, Brown, and Cocking 2000). The current cognitive approach encourages teachers to focus on what students know about the subject under study and to begin instruction with the intent of teaching for deeper understanding. High school science teachers must actively engage students in studying natural phenomena within familiar contexts and situations, which often extend beyond the science laboratory into the home and community. Deep understanding of natural phenomena and scientific inquiry must become a primary goal of the curriculum. In addition, students must be encouraged to monitor their own understanding of scientific content and process, noting how these ideas change during learning.

What Have We Learned From the Past?

The history of science education over the past 200 years illustrates why national committees have been assembled to initiate reform. The pressure to change school science stems from political forces to make the nation more

economically productive, militarily prepared, and physically healthy. A recurrent recommendation from national committees has been to expand the traditional mode of science teaching from one that stresses teaching science as a body of knowledge to one that stresses the development of fundamental scientific knowledge through inquiry-based learning.

Currently, science education stresses the importance of students developing a deep understanding of core scientific knowledge and the methods of science. The learning must encourage students to think and talk more like scientists. Although not all forms of instruction can be labeled teaching science as inquiry, this approach can be supported and complemented by other types of instruction in which investigative skills are refined, the applications of science are stressed, the history of science studied, and the nature of science discussed. Planning for this type of curriculum can also address students' needs and interests, perhaps better than a course of study centering primarily on the development of fundamental concepts and principles.

The challenge has never been greater for secondary school science teachers to understand, plan, and implement the science-as-inquiry approach—an approach that attempts to assimilate the recommendations of many professional committees while accommodating the pressures of a changing society.

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