From 1969 to 1986 Schwab produced six articles (the last two unpublished) on the various dimensions of the *The Practical*, the first three of which are included in a compilation by Ian Westbury and Neil J. Wilkoff. *Practical 1* gives his basic critique in terms of flights from the curriculum field. *Practical 2* demonstrates the proper use of the eclectic arts on theories through an imagined course in educational psychology. *Practical 3* focuses on the constitution and functions of the curriculum group. *Practical 4* gives special attention to the institutional role of the curriculum specialist as chairperson of the group. *Practical 5* and *Practical 6* describe the eclectic arts for development and use of commonplaces that can map pluralistic views of subject matter, using literature and psychology as examples.

**Legacy**

As a scholar and teacher Schwab pulled together such wide experience in the five bodies of disciplines necessary for curriculum development that he became a genuine polymath in education. He was quick to trace positions to unexpected consequences. Expressed in a down-to-earth no-nonsense rhetoric, this made him a formidable and provocative presence in public forums and the classroom.

Schwab’s concern for education as a deliberative activity connects him to John Dewey and American Pragmatism. His respect for the formulations and proper uses of theories connects him to the Aristotelian distinction between theoretical, practical, and productive activities. Internationally, educational practitioners in the European Didaktik tradition, especially in Germany and Norway, have recognized the *The Practical*.

Overall, Schwab’s continuing effect is that of Socratic gadfly whose stinging critiques have stimulated education by pointing out chronic deficiencies and indicating new directions for inquiry and action. The recurring nature of educational problems makes much of his work, such as that on defining and testing objectives, still applicable.

**See also:** Curriculum, School; Educational Reform, *subentries* on Overview, Reports of Historical Significance; University of Chicago.

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Thomas W. Roby IV

**SCIENCE EDUCATION**

**OVERVIEW**

Robert E. Yager

**PREPARATION OF TEACHERS**

Robert E. Yager

Science has become an important component in the K–12 curriculum in American schools—but less so than reading and mathematics. At the end of the twentieth century reading and mathematics received more attention, government support, and focus for testing. It was assumed that reading and mathemat-
ics must be mastered first and that these skills were essential before the study of science and social studies. Science is often not taught daily in elementary schools, does not receive major attention in middle schools, and is often organized around disciplines that emphasize college preparation in high schools.

The Role of Science and Technology Education

As the twentieth century ended, it was clear that science and technology played significant roles in the lives of all people, including future employment and careers, the formulation of societal decisions, general problem solving and reasoning, and the increase of economic productivity. There is consensus that science and technology are central to living, working, leisure, international competitiveness, and resolution of personal and societal problems. Few would eliminate science from the curriculum and yet few would advance it as a curriculum organizer. The basic skills that characterize science and technology remain unknown for most.

As the twenty-first century emerges, many nations around the world are arguing for the merger of science and technology in K–12 schools. Unfortunately many are resisting such a merger, mostly because technology (e.g., manual training, industrial arts, vocational training) is often not seen as an area of study for college-bound students. Further, such courses are rarely parts of collegiate programs for preparing new teachers. Few see the ties between science and technology, whereas they often see ties between science and mathematics. Karen F. Zuga, writing in the 1996 book *Science/Technology/Society as Reform in Science Education*, outlined the reasons and rationale for and the problems with such a rejoining of science and technology. A brief review of what each entails is important.

Although science is often defined as the information found in textbooks for K–12 and college courses or the content outlined in state frameworks and standards, such definitions omit most essential features of science. Instead, they concentrate wholly on the products of science. Most agree with the facets of science proposed by George G. Simpson in a 1963 article published in the journal *Science*. These are:

1. Asking questions about the natural universe, that is, being curious about the objects and events in nature.
2. Trying to answer one’s own questions, that is, proposing possible explanations.
3. Designing experiments to determine the validity of the explanations offered.
4. Collecting evidence from observations of nature, mathematical calculations, and, whenever possible, experiments that could be carried out to establish the validity of the original explanations.
5. Communicating evidence to others, who must agree with the interpretation of evidence in order for the explanation to become accepted by the broader community (of scientists).

Technology is defined as focusing on the human-made world—unlike science, which focuses on the natural world. Technology takes nature as it is understood and uses the information to produce effects and products that benefit humankind. Examples include such devices as lightbulbs, refrigerators, automobiles, airplanes, nuclear reactors, and manufactured products of all sorts. The procedures for technology are much the same as they are for science. Scientists seek to determine the ways of nature; they have to take what they find. Technologists, on the other hand, know what they want when they begin to manipulate nature (using the ideas, laws, and procedures of science) to get the desired products.

Interestingly, the study of technology has always been seen as more interesting and useful than the study of science alone. Further, the public has often been more aware of and supportive of technological advances than those of basic science.

Science (along with technology) in the school curriculum has assumed a central role in producing scientifically (and technologically) literate persons. Since 1980 the National Science Teachers Association (NSTA) has identified such literacy to be the major goal of science instruction. The organization also described what literacy would entail. Its *NSTA Handbook, 1999–2000* defined a scientifically literate person as one who can:

- Engage in responsible personal and civic actions after weighing the possible consequences of alternative options
- Defend decisions and actions using rational arguments based on evidence
- Display curiosity and appreciation of the natural and human-made worlds
• Apply skepticism, careful methods, logical reasoning, and creativity in investigating the observable universe
• Remain open to new evidence and realize the tentativeness of scientific/technological knowledge
• Consider the political, economic, moral, and ethical aspects of science and technology as they relate to personal and global issues

Whatever schools can do to produce graduates who have such skills defines the role for science education in schools. The curriculum is the structure provided to accomplish such goals. The 1996 National Science Education Standards set out just four goals, namely, the production of students who:

• Experience the richness and excitement of knowing about and understanding the natural world
• Use appropriate scientific processes and principles in making personal decisions
• Engage intelligently in public discourse and debate about matters of scientific and technological concern
• Increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their fields

History of Science Courses in American Schools
Early American public schools did not include science as a basic feature. The purpose of the early school was to promote literacy—defined to include only reading and numeracy. The first high schools primarily existed to prepare students for the clergy or law. Typical science courses were elective and included such technology courses as navigation, surveying, and agriculture. Not until the turn of the twentieth century did the current science program begin to form.

Physics began to be offered as a high school course in the late 1800s. It became even more common when Harvard University required it for admission in 1893; Harvard also required chemistry ten years later. Physics and chemistry were soon identified as college preparatory courses as other universities followed Harvard’s lead in requiring both for college entrance. Biology, the third high school course, was not identified until the 1920s—resulting from the merger of such common courses as botany, physiology, anatomy, and zoology.

Traditionally the high school curriculum has consisted of physics in grade twelve, chemistry in grade eleven, and biology in grade ten. Often schools have moved to second-level courses in each of these three disciplines; at times these advanced courses are titled Advanced Placement and can be counted toward college degrees if scores on national tests are high enough to satisfy colleges. This focus on school science as preparation for college has been a hindrance to the casting of science courses as ways to promote science and technology literacy.

Science below the high school level (grade ten) has a varied history. Science classes at this level became more common in the middle of the twentieth century with the creation of junior high schools—often grades seven, eight, and nine. In many instances the science curriculum was similar to the high school curriculum except that science was usually termed general science, with blocks for each course coming from biology, chemistry, physics, and earth science. There have been attempts to unify and to integrate science in these middle grades. With the emergence of substantial national financial support for curriculum and teacher professional development, however, the major effort in the 1960s was to create life, physical, and earth science courses for the junior high schools. During the 1970s and 1980s, middle schools were created with ninth grade returning to high schools (grades nine through twelve) and sixth grade becoming a part of the middle schools. As the National Science Education Standards emerged in 1996, the middle grades were defined as grades five through eight.

Middle school philosophy calls for teams of teachers (from all facets of the curriculum) to work with a given set of middle school students and to unify and relate all study for those students. Project 2061, formulated in the late twentieth century, is a reform project that ties the curriculum together, especially science, mathematics, technology, and social studies.

Elementary school science was rarely found until the middle years of the twentieth century. Although there were textbooks and courses listed in the offerings, science frequently did not get taught. This was because teachers placed reading and mathematics first; they often lacked preparation in science, and there was no generally accepted way of measuring science learning across grade levels.

During the 1960s and 1970s several national curriculum projects were funded, developed, and of-
ferred across the K–12 years. This continued into the twenty-first century, with many programs that provide ways to meet the visions of the National Science Education Standards supported by the National Science Foundation. Unfortunately not many of these ideas are in typical textbooks offered by the major publishers, who, understandably, are more interested in sales and offering what teachers, schools, and parents want. These textbooks are often quite different from what reform leaders and cognitive science researchers envision for an ideal science curriculum.

**Comparing Science Education Requirements around the World**

Reformers in most industrial nations across the world advocate similar school reforms of science with new goals, procedures, materials, and assessment. The United Nations Educational, Scientific and Cultural Organization (UNESCO) has initiated a reform effort for the twenty-first century that is targeted for developing nations and relates science to technology. Many educational teachers across the world call openly for a science curriculum that is responsive to personal needs, societal problems, and attentive to technological as well as scientific literacy. New attention to assessment and evaluation has arisen from the Third International Mathematics and Science Study.

Elementary school science is similar the world over with the focus being hands-on and minds-on activities that are not discipline-based. Often middle schools have science programs that frequently focus on problems. In the United States some of the major science programs include Event-Based Science and Science Education for Public Understanding Program. Similar programs exist elsewhere, especially in the United Kingdom, Israel, the Netherlands, and Australia, and in other European countries.

Although the goals for high school science are the same in most countries, the traditional discipline-based courses (biology, chemistry, and physics) in the United States are typical yearlong courses for grades ten, eleven, and twelve. Most other countries organize the secondary curriculum to respect discipline divisions, but spread the courses over a five- or six-year sequence. They do not delay physics and chemistry to grade eleven or twelve or place biology solely in grade ten.

The interest in international comparisons has never been greater. There is great concern that testing and learning is based on little other than students’ ability to recite definitions and/or to solve mathematical problems given to them. Cognitive science research indicates that most of the brightest science students can do little more than to repeat what they have been told or what they read, or to duplicate procedures they have been directed to follow. Educators now want more evidence that students can use information and skills in new situations. Such performance is demanded to assure scientific and technological literacy.

**Trends, Issues, and Controversies**

Science education is evolving once again—as it has since the emergence of public schools in the United States—to a focus on mastering basic concepts and skills that can be used in new situations. Yet, in order to truly accomplish this, contexts need to be established first. Concepts and process skills are desirable end points. But if real learning is to occur, concepts and skills cannot be approached directly and used as organizers for courses and instruction. Without the proper background, students do not understand and are rarely able to use the information and skills that are taught. This explains why science lacks popularity and why most students stop their study of science as soon as they are permitted to do so. Little is gained by simply requiring more for a longer period of time.

Another trend is the open inclusion of technology with the study of science. Contrasting the two can help develop an awareness of the history, philosophy, and sociology of both. Since more students are interested in technology than in science, including technology within science education can provide a vehicle for getting students more involved with basic science. Instead of authorities proclaiming science as important and useful, students discover that for themselves as they develop and use new technologies.

Taking statements of goals seriously is another trend. Goals can and should provide the framework for the curriculum, indicate the instruction selected, and provide form and structure for evaluating successes and failures. Each of these critical factors provides a basis for doing science in education.

The involvement of more people and organizations in the process of educating youth is another important trend. Responsibility for setting science goals, choosing instructional strategies, determining
curriculum structure, and defining assessment efforts must rest with teachers as well as with students. Outside agencies—administrators, state departments of education, national governments, professional societies, and the public—all must be involved and are integral to the plan to improve science education.

Major issues include how to evaluate and enlarge goals, how to change instruction, how to move assessment from testing for memory and repetition (copying) of procedures to making these constructs and skills a part of the mental frameworks of the students. When does real learning pass from mimicry to understanding and personal use?

Engaging student minds requires changes that are essential to current reform efforts. According to Vito Perrone, such engagement is accomplished when:

1. Students help to define the content—often by asking questions.
2. Students have time to wonder and to find interesting pursuits.
3. Topics often have strange features that evoke questions.
4. Teachers encourage and request different views and forms of expression.
5. The richest activities are invented by teachers and students.
6. Students create original and public products that enable them to be experts.
7. Students take some actions as a result of their study and their learning.
8. Students sense that the results of their work are not predetermined or fully predictable.

Can science teachers really become major players in cross-disciplinary efforts in schools? Can they embrace technology as a form of science and/or an entry point to it? Can they refrain from telling students what they want them to do and to remember (for tests)? According to the National Research Council’s 1998 book *Every Child a Scientist*, Carl Sagan argued that “every student starts out as a scientist.” Students are full of questions, ready to suggest possible answers to their questions. Unfortunately, however, most lose this curiosity as they progress through their science studies. In typical schools they rarely design their own experiments, get their own results, and use the results for any purpose. They do not see or practice science in any full sense.

Major controversies remain. But why should this not be so? Science is an activity where there are changes, differences of opinions, differences in designing good experiments or making calculations, and differences in collecting evidence and convincing others of the validity and accuracy of the evidence offered.

Certainly most educators remain committed to the model of relying on the science found in textbooks, state curriculum frameworks, and standards documents. They are committed in spite of the research evidence that highlights the advantages of new approaches to learning and new ways of measuring learning and understanding. Humans tend to resist change—even when they know it will occur. It is sad that science educators do not lead in the attack on the unchanging curriculum and lack of attention and use of the new information on how humans learn.

See also: Curriculum, School; Elementary Education, subentries on Current Trends, History of; National Science Teachers Association; Science Education, subentry on Preparation of Teachers; Science Learning; Secondary Education, subentries on Current Trends, History of; Technology in Education, subentry on School.

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Programs for preparing science teachers in the United States are numerous—numbering about 1,250. These programs vary considerably, though most require a major in one discipline of science and a strong supporting area. The professional sequence varies greatly with smaller programs unable to maintain a faculty with expertise in science education per se. The programs generally consist of half the credits in science, a quarter in education, and a quarter in liberal arts requirements. In the 1990s the quantity of preparation in science and in science education increased—often making it difficult to complete programs as part of a four-year bachelor’s degree program. Fifth-year programs that include more time spent in schools with direct experience with students are becoming the norm.

Historical Background

Early in the 1800s science teachers typically had no formal preparation; often they were laypersons teaching such courses as navigation, surveying, and agriculture in the first high schools. By 1870, with the emergence of the first teacher training colleges, some science teachers completed formal study of science in colleges. Qualifications for specific teaching, however, varied considerably across the United States.

In the early 1890s Harvard University required completion of a high school course in physics for admission. This spurred the beginning of the science curriculum in American schools. Ten years later Harvard added chemistry to its requirements for admission. Many other colleges and universities followed suit. High school science classes became gatekeeper courses for college admission—a situation that turned out to be a continuing problem for science in schools and for the preparation of science teachers.

By the end of World War II, the place of science in school programs had attained universal acceptance. Teacher education programs were standardized to include science methods courses and student teaching after a year of introduction to education and educational psychology courses. School programs were to provide functional science experiences, that is, skills and knowledge that students could use. Faculty at preparatory institutions became the chief proponents for a useful science program for students.

Science education changed in the 1950s as leaders and the general public demanded improvements to match the Soviet successes in space. National spending for improving school science programs and the preparation of science teachers were made a priority in the National Science Foundation (NSF). Scientists were called to provide leadership in the reform of school programs and the development of better-prepared teachers.

In the 1970s these national efforts to improve school programs and teacher education, including the goals for science teaching, were reassessed. The public had become disillusioned with the expendi-
tures for science teacher enhancement and curriculum development projects. The NSF Project Synthesis effort established four new goals: science for meeting personal needs, science for resolving current societal issues, science for assisting with career choices, and science for preparing for further study.

In this climate the NSF established a new program to influence science teacher education directly.Called the Undergraduate Pre-Service Science Teacher Education Program (UPSTEP), its premises included the following:

1. Effective preservice programs integrate science and education and often require five years.
2. Science faculties are important ingredients in program planning, teaching, and program administration.
3. The preparation of an effective science teacher involves more than providing a student with up-to-date content and some generalized teaching skills.
4. Effective programs involve master teachers, school and community leaders, and faculty members.
5. Teacher education can be evaluated and used to improve existing programs.
6. Effective programs should include advances in computer technology, educational psychology, philosophy, sociology, and history of science.

**Current Structure and Organization**

Most of the 1,250 institutions that prepare science teachers start with the assumption that an undergraduate major in one of the sciences is a must. Many teacher education programs merely require science courses (typically about one-half of a degree program) and increase the number of methods courses and associated practica (experiences in schools) prior to student teaching. Many institutions moved to a five-year program and/or the completion of a master’s degree before licensure.

In the 1990s the U.S. Department of Education funded studies, known as Salish I and Salish II, to discern the condition of preservice teacher education programs in the United States. Salish I was a three-year study of programs and graduates from ten different universities across the United States. The study’s major findings included the following:

1. During their initial years of teaching, most new science teachers use little of what teacher education programs promote.
2. Few teacher education programs are using what is known about science as envisioned by the National Science Education Standards.
3. The courses comprising teacher education programs are unrelated to each other.
4. There are few ties between preservice and in-service efforts.
5. Support for teacher education reforms has been largely unrecognized and underfunded.

Salish II involved fifteen new universities, which agreed to alter some aspects of their teacher education programs and to use research instruments from Salish I to determine the effectiveness of the changes. Major findings from Salish II were as follows:

1. Significant changes in teacher education majors can be made during a single year, when part of a collaborative research project.
2. There is strength in the diversity of institutions and faculty involved with science teacher education.
3. Science instruction at colleges must change if real improvement is to occur in schools.
4. Collaboration in terms of experimentation and interpretation of results is extremely powerful.

**In-Service and Staff Development Programs**

A persistent problem has been the lack of articulation between pre- and in-service science teacher education. NSF support for in-service teacher education from 1960 to 1975 focused on updating science preparation in an attempt to narrow the gap. In fact, NSF efforts often tended to deepen the problem. The NSF assumed that science teachers needed only more and better science backgrounds and the NSF model was simply one of giving teachers current science information, which they were to transmit directly to their students. What was needed was a set of intellectual tools with which teachers could evaluate the instruction they provided.

According to David Holdzkom and Pamela B. Lutz, authors of the 1984 book Research within Reach: Science Education, effective science teachers must have a broader view of science and of education. They need to be in tune with the basic goals of science education in K–12 settings and be prepared to deal with all students in efforts to meet such objectives. H. Harty and Larry G. Enochs, in a 1985 article in the journal School Science and Mathematics,
offered an excellent analysis of the form in-service programs should take, contending that such programs should:

- Have a well-defined, organized, and responsible governing mechanism
- Involve teachers in needs-assessment, planning, designing, and implementing processes
- Provide diverse, flexible offerings that address current concerns of the practitioner and that can be used readily in the classroom
- Include an evaluation plan of the individual components of the program and their effect in the classroom.

The content versus process debate continues and is counterproductive at best. Science cannot be characterized by either content (products produced by scientists) or process (behaviors that bring scientists to new understandings). Effective teacher education programs cannot be developed if science preparation focuses on content mastery and the education component focuses on process. Teachers must learn to use both the skills and processes of science to develop new knowledge of both science and teaching. They need to use the research concerning learning, such as the National Research Council’s 1999 book How People Learn.

In the late 1990s NSF initiated new programs designed to improve in-service teachers—and later preservice teachers as well. These systemic projects were funded at approximately $10 million each in about twenty-five states. Later urban, rural, and local systemic projects were conceptualized and funded. Teacher education programs involving several college/university situations were also funded to relate in-service efforts directly to the preparatory programs. These collaborations often tied institutions together in order to share expertise, faculty, and program features.

**Major Trends, Issues, and Controversies**

Major trends in science teacher education include:

- Extending the pedagogical facet of the program over two calendar years with extensive school practica provided as places to try new ideas
- Replacing four-year bachelor’s programs with five-year master of arts in education programs
- Using the National Science Education Standards for visions of goals for all students, effective teaching strategies, content and curricula features, assessment strategies, and staff development
- The extensive collaborating of all stakeholders (administrators, parents, community leaders, and all teachers across the curriculum) for reform efforts
- Broadening the view of science to include the human-made world (technology) as well as natural science, science for meeting present and societal challenges, a focus on inquiry as content and skills that characterize science, and the history/philosophy/sociology of science.

Some of the major unresolved controversies include:

- Limiting the number of institutions preparing science teachers
- Teaching teachers, over a five-year program, in the same manner that they should teach
- Using the four goals for school science to prepare teachers to internalize the National Science Education Standards, including experiencing science as: an investigation of natural phenomena, a means for making sound personal decisions, an aid in public discussion and debate of current issues, and a means of increasing economic productivity.

Optimism for even greater successes with meeting the goal of scientific literacy for all is a central focus for science teacher education. Certainly the new Centers for Learning and Teaching that NSF began funding in 2000 are designed to help. By definition they combine preservice and in-service science education—making the two seamlessly connected. They require a common research base while also assuring that a major effort of the center will be to extend that research base. They must design and implement new doctorate programs to prepare future leaders. The history of science education is replete with identification of current problems, new ideas for their resolution, major national funding (since 1960), and then almost immediate abandonment after initial trials are not successful. The current challenge facing science teacher education is whether there is adequate national commitment, determination, and know-how to realize the visions elaborated in current reform documents.

**See also:** National Science Teachers Association; Science Education, subentry on Overview; Science Learning.
The K–12 U.S. science education standards, now published state by state, without exception cite competence in scientific investigation as an important curriculum goal from the early grades on. Students, it is claimed, should be able to formulate a question, design an investigation, analyze data, and draw conclusions. Reference to such skills in fact appears in discussions of curriculum objectives extending well beyond the discipline of science. The following description, for example, comes not from science edu-