DOCUMENT RESUME

ED 374 997 SE 055 236

TITLE Active, Meaningful Science Learning: A Guidebook.
INSTITUTION Midwest Consortium for Mathematics and Science Education, Oak Brook, IL.; North Central Regional Educational Lab., Oak Brook, IL.
PUB DATE [94]
NOTE 19p.
AVAILABLE FROM North Central Regional Educational Laboratory, 1900 Spring Road, Suite 300, Oak Brook, IL 60521-1480.
PUB TYPE Guides - Non-Classroom Use (055)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Educational Change; Elementary Secondary Education; Science Curriculum; *Science Education; Science Programs; Technology
IDENTIFIERS *National Science Education Standards

ABSTRACT

Science education reform is an ongoing, forever changing process. The purpose of this booklet is to provide a brief overview of the players in science education reform, the similarities in their underlying beliefs, and the essential changes that need to be made in science education to ensure maximum use of resources that promote effective learning environments for all students. Topics that are briefly described include: emerging science education standards; student learning; content and process; curriculum/instruction; assessment; and technology. Also included is a brief list of resources, successful science programs and printed materials, and a checklist to evaluate the science activities in any school or school system. (ZWK)

NCREL, a not-for-profit organization, works to improve education in Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, and Wisconsin. It also operates the Midwest Consortium for Mathematics and Science Education.

Active, Meaningful Science Learning:

A Guidebook

Introducing

The Importance of Science Education

Science education is of critical national importance for a number of reasons. In the past, science education has been valued because of its key role in the nation's economy, the drive to compete economically and technologically with other nations, and the need for scientific knowledge in an increasingly technological workplace. Today, the economic impact of science is as important as ever, but we now know that science education is also very important for other compelling reasons.

Science education helps to maintain a strong participatory democracy. Citizens who are scientifically literate, who understand key concepts of science and technology, and who are able to use this knowledge in everyday life are able to understand complex public policy issues, such as environmental and health concerns, and to grasp the complexities of rapid change, such as the restructuring of our economy and shifting population trends.

Science education enriches people's lives and yields high dividends because it models disciplined inquiry. A solid grounding in science helps us explore and understand the natural environment and contemporary culture, while it opens our minds to the aesthetic and intellectual pleasures that surround us.

Learning and using scientific knowledge is a lifetime pursuit, particularly in an age permeated by science and technology. As we approach the 21st century, we must accept science as a basic subject to be taught in an understandable manner to all students.

Introduction

For generations, educational programs have been designed for "mastery of facts." Teachers and parents who were educated in this tradition felt compelled to perpetuate this mind-numbing approach and to construct an educational warehouse of facts from which students would be supplied with information. Even today, some educators, policymakers, and textbook publishers reinforce this fact-driven educational system. Learning is equated with successfully memorizing test materials. In turn, this emphasis on factual recall profoundly affects how teachers teach and how and what students learn. A traditional United States science education program discourages real learning not only in its overemphasis on facts, but in its very structure, which inhibits making valuable connections between facts.

In elementary school, students are inundated with scientific terms that are not connected to everyday life and therefore cannot lay the foundation for continued, meaningful learning in science. Most secondary schools organize their science programs so that each year students pursue one discipline from the descriptive to the theoretical, with little reference to prior science learning from that course or from other science courses. These programs make even less reference to what will be learned in future science courses. As a consequence, many students never continue their science education. The emphasis on facts and rote learning and the difficulties that students encounter in grasping theoretical concepts without a sufficient grounding in experience deter many from pursuing more advanced studies in science.

Although consensus on a vision for science education is still evolving, science education reformers agree that current U.S. science education is deficient. Reformers also agree on the characteristics of good science instruction at the elementary, middle, and high school levels.

Based on this agreement, reformers of science education, like reformers of mathematics education, are developing new approaches to education using the emerging science standards. Teachers, researchers, and government officials have come together seeking strategies to help students develop a deeper understanding of science and the ability to apply learned concepts to new situations or problems.

The purpose of this booklet is to introduce you to the major players in science education reform, the similarities in their underlying beliefs, and the essential changes that need to be made in science education to ensure maximum use of resources that promote effective learning environments for all students. You also will find a list of resources, successful science programs and printed materials, and a checklist to evaluate the science activities in your school or school system.

If you are interested in more information about science reform in schools, please contact:

Midwest Consortium for Mathematics and Science Education
North Central Regional Educational Laboratory
1900 Spring Road, Suite 300
Oak Brook, Illinois 60521-1480
1-800-356-2735

Emerging Science Education Standards

National standards for elementary and secondary school science education are still evolving, but all entities involved in the reform effort agree that science education must change and that one-dimensional, fragmented reform efforts will not work. It is clear to all that reform must be comprehensive in scope and systemic in execution. It must address many dimensions simultaneously.

Many efforts are underway to chart new directions in science education to bring about significant improvements in the current system. Teachers and schools across the nation are striving to change the system, and in some school districts and states school reform is now the order of the day. Leading the most significant reform efforts are three projects by national science organizations, which are listed below:

National Science Education Standards Project—The National Research Council's (NRC's) goal is to develop and publish National Science Education Standards, K-12, that represent the consensus of scientists, science educators, and the public on the characteristics of quality science education for all students.

Project 2061—This project by the American Association for the Advancement of Science (AAAS) is dedicated to transforming K-12 science education for the 21st century by providing a coordinated set of reform tools for school districts to use in developing their own curricula so that all students achieve science literacy.

Scope, Sequence, and Coordination (SS&C)—The National Science Teachers Association (NSTA) seeks to reform science at the secondary level through carefully sequenced, well-coordinated instruction in all of the sciences, which all students will study every year for seven years so that they acquire a greater depth of understanding in science.

While the reform efforts of the main players in the science education standards process are supported by different organizations, it is important to note that the similarities in their efforts outweigh the differences. Each program addresses standards that affect curriculum, instruction, and assessment. Moreover, NSTA specifically endorsed Project 2061's goals and incorporated them into its core curriculum and defining documents, *The Content Core: Voumes I and II.*

Student Learning

Many science education reforms are based upon constructivist views of the science learner. *Constructivism* is a dynamic and interactive model of how humans learn. Constructivists believe that all students can become competent learners. Students redefine, reorganize, and elaborate their existing concepts through interaction with peers, objects, and events in the environment. Students "interpret" objects and phenomena and subsequently explain their world in terms derived from their current conceptual understanding. For example, when students learn about photosynthesis, they connect their emerging understanding to what they already know about "food" and how they think plants make their food.

Research indicates that when students are actively engaged in science and are allowed to build meaning out of both old knowledge and new information from sources such as experiments and conversations, they are able to construct an understanding of major concepts that is more adequate than their original explanation. Students who are not given the opportunity to express their ideas and are not challenged to rethink those ideas become passive science learners. In the traditional classroom, the teacher simply "pours in" information on top of pre-existing ideas, and the student "stores" the new information until it is needed on a test.

The end product of constructivist learning is much more than rote memorization. It is a true understanding of how the world works and why this information is useful. Students inquire, reflect, and propose explanations, then explore further in a manner that is meaningful to them. They engage in the same process that leads scientists to describe and explain new scientific phenomena.

Content and Process

The science frameworks and textbook content in the United States vary considerably from state to state, across districts and schools, and even among same-grade classrooms within a single school building. At the elementary school level, no single science topic will have been taught in all or even most of the classrooms. This haphazard approach to the nation's science curriculum has resulted in student shortcomings in two general areas: knowledge and critical thinking.

Researchers believe that students' knowledge in scientific areas such as biology, chemistry, and physics is remarkable for the lack of deep understanding and the existence of many alternative and inadequate conceptions about the disciplines. While students may have information about portions of a discipline, they lack strong connections among those portions.

In the area of critical thinking, the problem of fragmented knowledge is exacerbated by students' lack of skill in acquiring and evaluating new information. Because of their limited knowledge, students are unprepared to work effectively in a technological society when they leave school. Furthermore, failure to master critical thinking skills makes it difficult for such students to adapt readily to new settings.

According to researchers, these shortcomings are the outcomes of traditional primary and secondary level curricula. Students are not offered real opportunities to acquire critical thinking skills because of a preoccupation with learning facts and rote learning.

In secondary school, where emphasis is placed on breadth of coverage, the situation is compounded. Science courses allow—even encourage—students to proceed without building strong connections among the various concepts to which they are exposed.

Subjects are not explored in depth and, as a result, students cannot evaluate new information critically.

Even as science curriculum standards are being defined, several models are available for consideration. One model focuses the curriculum on "themes"—systems, chance, diversity, cause and effect, and so on. The curriculum develops ideas that extend beyond individual facts and concepts and transcend disciplinary boundaries. The premise of this approach is that active learning coupled with a thematic curriculum is the best way to provide students with the education they will need as professionals and/or productive citizens.

Project 2061 also has had success with new learning methods that do not require memorizing facts, terms, and bits of unconnected information. A consensus is developing among science educators that students can acquire a deeper understanding of science by covering fewer topics—the principle of "less is more." Students learn a few concepts in depth, which they can then apply to new situations or problems. Project 2061 has identified those concepts and habits of mind that characterize a scientifically literate individual.

Another model, identifying "curriculum" as science "content standards," is being promoted by the National Committee of Science Education Standards and Assessment. While the Committee recognizes that science curriculum is derived from the knowledge base of the natural sciences, "science content" should not be limited to the concepts, principles, facts, laws, and theories that compose the body of scientific knowledge. Instead, according to the Committee, the following four general categories of *school science content* define the breadth of science content and provide organizers for the standards:

- Science as Inquiry
- Science as Subject Matter

- Science Connections
- Science and Human Affairs

The Committee believes that an effective science curriculum is one that routinely weaves together these important aspects of what students should know and do in a variety of creative ways.

A curriculum project developed by the National Science Teachers Association adheres to the "less is more" philosophy as well. The project, called *Scope, Sequence, and Coordination of Secondary School Science (SS&C)*, believes that students should experience the natural world before they learn the terms, symbols, and equations that scientists use to explain it. The curriculum engages students in the early grades with science problems and issues of personal concern, and in the later grades with more global science consideration. Gradually, science is placed within a larger context, helping students to relate scientific knowledge to themselves and their lives.

The explosion of scientific knowledge in the 20th century confronts us with the need to choose carefully the material to be presented at every level. All too often, curriculum selection is driven by the calendar. If a scientific fact was unearthed last year, then it must be important; if teachers understand something in great detail, then that detail should be taught.

A science curriculum should be a dynamic enterprise—it is both a product and a process. It should be a program of activities undertaken by students and teachers alike. Lessons should evolve as they are taught and learned. The curriculum must help students link, interpret, and explain new information in light of students' existing knowledge.

Curriculum/Instruction

It is difficult to separate curriculum from instruction. The teacher is the key to individual student achievement and to the success of any curriculum program. Even with the advances in instructional methods and technology, the old idea is still valid that once the classroom door is closed, the teacher is the person responsible for what the students learn.

Generally, science is taught in elementary schools by homeroom teachers, most of whom do not have majors or minors in the sciences. Those teachers insecure in their science knowledge are more likely to use precious time for other, tested, curricular areas, or to introduce misconceptions. Teachers that have to teach a broad range of subjects in any one year find it difficult to allot significant time to "hands-on" discovery and probing for higher-order thinking.

Students should leave elementary school with a strong love and appreciation of nature and the world around them. They also should recognize that science is an important way to learn about the world. If elementary school teachers are not secure in their own knowledge of science, quality science instruction will not occur.

Secondary science teachers use textbooks extensively. Indeed, textbooks are the organizing framework for the vast majority of high school science courses. Reading the textbook and listening to teacher lectures is the dominant method of instruction in secondary schools.

Convincing evidence exists that students become more active learners when teachers function as facilitators, asking provocative questions, providing open-ended experiences, monitoring student progress, challenging assumptions, encouraging alternative solutions and explanations, and providing a psychologically safe classroom environment for sharing viewpoints without fear or ridicule.

[redacted]

It is very important to treat science as a first-priority subject, beginning in the formative years of elementary school. The failure to do so is among the reasons that secondary school students perform poorly and develop negative attitudes toward science.

Teachers should have a personal vision of good science, a commitment to personal change in their teaching practices, and adequate resources to make changes where needed. A change in the school culture also is required if science education is to be strengthened. Teachers must be secure in their content knowledge and committed to empowering students, and the schools must be places where teachers feel comfortable proposing and trying out new instructional strategies and materials and where networking with peers and superiors routinely occurs. The school's environment must foster open communication, collegiality, support, trust, and learning on the job.

Assessment

Curriculum, instruction, and assessment are more effective if they derive from and reinforce each other. As curricular and instructional approaches change, it is important to assess whether significant improvements in student learning have occurred. There are many ways to determine a student's understanding of the subject area, but historically schools have been driven by standardized test scores and report cards that compare schools.

Student learning and attitudes in science should be viewed and assessed from multiple perspectives. Students learn science in other school courses, especially in mathematics and technology education. Students learn science in a multitude of contexts in which technology is used. Science also is learned outside of school—sometimes more than in school. Therefore, assessment approaches that include only school-, textbook-, or laboratory-type settings for science may not allow many students to demonstrate their knowledge and ability in science. Additionally, ample evidence suggests that students can demonstrate high achievement on school-based standardized science assessments and still have misconceptions about fundamental science concepts.

Assessment in science should promote and encourage learning. It should focus on what students can do rather than what they cannot do and avoid testing what they have memorized, but not understood.

The main role of assessment is to improve instruction. Good teachers reevaluate the effectiveness of their instruction as they gather information on students' progress and change their teaching approaches to increase students' learning and competencies. Good teachers also use multiple means of assessment to determine the extent of students' comprehension of science concepts, as well as their ability to develop scientific habits of mind and to understand the scientific endeavor. These assessments can be surveys, inventories, portfolios, technology-based tools, journals, oral presentations, experiments, and other "artifacts" of structured inquiry. In this way, assessment information can enhance science instruction, while providing a look at the science achievement of individual students and the class as a whole. Teachers also must have access to adequate resources to implement an excellent assessment process.

Technology

The emergence of a vision of the information that technology offers to science education is the most important product of educational technology of the past two decades. According to this new vision, students tackle harder problems; work on larger-scale, more meaningful projects; have greater responsibility for their own learning, and are able to work effectively in teams comprising different genders, ethnic backgrounds, and personalities.

Technology has provided science with powerful tools that can be used to observe, measure, analyze, communicate, and test hypotheses. It has something to offer every aspect of students' science projects; it can expand the range of possible projects; offer new opportunities for collaboration and communication; simplify acquiring and displaying data; provide mechanisms to control experiments; and increase the sophistication of theory building, modeling, and data analysis that students perform. Technology also can provide new outlets for creative expression and grant access to vast databases of information.

The use of technology in science should be based on the fundamental premises of the nature of science, what students should know about science, and what skills they should have. Technology can allow students to learn ideas through the manipulation of systems or conditions that do not exist in nature. Technology tools and communications networks can connect students to interesting problems in science, students to other learners, and students and teachers to other teachers and scientists.

In addition to its role as a pedagogical tool, technology can address many other problems in science education. Technology can be used to determine what students really understand about a particular concept, offer intelligent advice to teachers about the experiences that can build student understanding; extend the school day, week, and year; bring quality science instruction to students in remote regions of the country or in educationally impoverished areas; and provide access and opportunities to learn for students who may be limited by barriers of language, disability, socioeconomic status, or low expectations.

What Can You Do?

You can help reform science education by doing the following:

- Use the checklist below and on the next page of this booklet to examine your school's science activities to determine where you are on the path to reforming science education.
- Review the list of resources and contact the publisher/developer for further information and assistance.

Checklist for Assessing Science Programs

Note: The following checklist items are program dimensions that range along a continuum. They are intended to help you start thinking about the degree to which your programs are creating and sustaining student-centered communities of scientific inquiry.

Vision

- ☐ Science education is important for all people.
- ☐ Quality science education is accessible to all students.
- ☐ Science is viewed as an active, constructive process.

Curriculum and Instruction

- ☐ Curriculum has a broad range of content.
- ☐ Curriculum is based on themes and sequence.
- ☐ All students are included in all aspects of the curriculum.
- ☐ Instruction is conducted within a variety of contexts. Connections are deliberate so that students can make sense of science.

[redacted]

- ☐ Instruction is based on problem situations found in the real world.
- ☐ Instruction is student-centered, actively involving students in their own learning.
- ☐ Instruction is experience-centered, with direct observation and manipulation of phenomena used as a means of building science concepts.
- ☐ The teacher operates as "facilitator" of communication, not as "dispenser" of knowledge.
- ☐ The teacher builds upon students' prior knowledge.
- ☐ Appropriate technology is used to enhance students' science comprehension.

Assessment

- ☐ The goal of assessment is to promote and improve instruction and learning.
- ☐ Multiple assessment tools are used.

Resources

American Association for the Advancement of Science. (in press). *Benchmarks for Science Literacy (Part I: Achieving Science Literacy), Project 2061.* Washington, DC: American Association for the Advancement of Science.

Nancy Kober. (1992). *EDTALK: What We Know About Science Teaching and Learning.* Washington, DC: Council for Educational Development and Research.

The National Science Teachers Association. (1992). *The Content Core: A Guide for Curriculum Designers, Volume I and Volume II.* Washington, DC: Author.

Schwartz, A.T. (Ed.). (in press). *Chemistry in Context: Applying Chemistry to Society.* Washington, DC: American Chemical Society.

Additional Resources

Eisenhower National Clearinghouse for Mathematics and Science Education

The Clearinghouse collects, stores, and disseminates mathematics and science instructional materials to K-12 teachers and others. Resources available include textual materials; manipulatives; audio, video, and other images; software; databases that include a catalog of materials, text, and images, listing of federal and other programs in science and mathematics education, abstracts, and evaluations; and an electronic network through which teachers can communicate and contribute materials and evaluations.

For information about the Eisenhower National Clearinghouse, contact:

Dr. Michael H. Klapper
Eisenhower National Clearinghouse for
Mathematics and Science Education
1314 Kinnear Road
Columbus, OH 43212-1194
(614) 292-7784

The National Center for Science Teaching and Learning (NCSTL)

An educational think-tank that initiates goal-oriented, noncurricular research to improve K-12 science and mathematics teaching and learning. These factors include social and cultural attitudes, public expectations and societal incentives, economic and political forces, new technologies, and content integration.

For information about NCSTL, contact:

Michael D. Aiello
Program Manager
The National Center for Science Teaching
and Learning
1929 Kenny Road
Columbus, OH 43210-1015
(6140 292-3339

Search, Solve, Create, and Share (SSCS)

A K-12 problem-solving instructional model that provides students with concrete experiences that can be used in learning meaningful science. Students are encouraged to conduct a search of what is known about a specific problem and to extend that knowledge base through application or problem solving.

For information about SSCS, contact:

Dr. Edward L. Pizzini
Science Education Center
The University of Iowa
Iowa City, IA 52242-1478
(319) 351-0946

M
S
C

Midwest Consortium
for Mathematics and
Science Education

Midwest Consortium for Mathematics and
Science Education
North Central Regional Educational Laboratory
1900 Spring Road, Suite 300
Oak Brook, IL 60521-1480
1-800-356-2735