DOCUMENT RESUME

ED 303 319 SE 050 266

AUTHOR	Motz, LaMoine L., Ed.; Madrazo, Gerry M., Jr., Ed.
TITLE	Third Sourcebook for Science Supervisors.
INSTITUTION	National Science Supervisors Association, Washington, D.C.; National Science Teachers Association, Washington, D.C.
REPORT NO	ISBN-0-87355-075-7
PUB DATE	88
NOTE	194p.; Photographs may not reproduce well.
AVAILABLE FROM	National Science Teachers Association, 1742 Connecticut Avenue, NW, Washington, DC 20009 (Stock No. PB-63, $16.00, 10% discount on 10 or more).
PUB TYPE	Books (010) -- Collected Works - General (020) -- Guides - Non-Classroom Use (055)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Educational Research; Elementary School Science; Personnel Evaluation; *Program Evaluation; *School Safety; *Science Education; *Science Facilities; *Science Instruction; *Science Supervision; Science Teachers; Secondary School Science

ABSTRACT

Science supervisors have a complex and difficult job. They must have the abilities, training, and experience of scientist, educator, administrator, and politician. A science supervisor must be a master teacher, both in practice and in the knowledge of teaching methods, research on learning, and insight into the development of children. Another important role of the science supervisor is the promotion and support of science teaching with teachers, administrators and the community. This sourcebook consists of a collection of 24 articles by various authors concerning six major areas of science supervision. These areas include: (1) trends for the future; (2) the viability of science programs and supervision; (3) staff development; (4) safety in laboratories and classroom facilities; (5) the evaluation of teachers and programs; and (6) research about science supervision. (CW)

Third Sourcebook for Science Supervisors

Published by NSTA Publications
1742 Connecticut Avenue NW
Washington, DC 20009
Shirley Watt, *Managing Editor*
Diana Holmes, *Editorial Assistant*

Designed by Robert Sugar, AURAS Design, Inc.

Stock Number PB-63
ISBN 0-87355-075-7

Printed in the United States of America

Third Sourcebook for Science Supervisors

Editors: LaMoine L. Motz
&
Gerry M. Madrazo, Jr.

National Science Supervisors Association
National Science Teachers Association

Foreword

Science supervisors, or department chairpersons, have a complex and difficult job. They must have the abilities, experience, and training of scientist, educator, administrator, and politician. In explaining this concept to other supervisors, I often draw a series of concentric circles, with the inner circle labeled "Science," the next circle labeled "Teaching of Science," and the larger, more encompassing circle labeled "Supervising Science Teaching." The concentric circles represent the various dimensions of being a science supervisor. Supervisors must first be scientists, in the sense that they have an in-depth knowledge of at least one scientific field, and the ability and willingness to stay current in that field. The lack of this competence makes it very difficult to work with other science teachers and scientists in the community. Not only must a science supervisor know his or her content area, he or she must have the ability to help both students and teachers learn it. A science supervisor must be a master teacher, both in practice and in the knowledge of teaching methods, research on learning, and insight into students' developmental stages. It goes without saying that a supervisor must have successful experience as a classroom teacher; in addition, he or she must be able to capture the spirit and science of teaching and communicate it to other teachers.

Finally, and perhaps most important for this particular job, the supervisor must promote and support the role of science teaching with teachers and other key decision makers in the administration and community. By translating the needs of teachers and students for the key policy makers within a school district, the science supervisor becomes part politician. In addition, it is important to scan the community for those elements that will affect the future direction of science education and communicate them back to the teachers. The quote attributed to Einstein that "politics is much more difficult than physics" often summarizes the frustration and difficulties of this dimension of the supervisor's job.

This *Sourcebook*, with contributions from many university professors and practicing science supervisors, has invaluable articles that will help all of us accomplish the various dimensions of our job. Appreciation should be given to Gerry Madrazo and LaMoine Motz for their skilled and diligent effort in putting this sourcebook together.

HAROLD PRATT
NSSA PAST-PRESIDENT, 1985-86

Preface

As the twenty-first century approaches, science education must find new directions. To be effective, science education must focus on relevance for the learner. As educators, we must help students develop the skills and knowledge base they need to understand the relationship of science, technology, and society. As well, we need to design and foster interdisciplinary work between science and the arts, languages, and social sciences. It is only when they see these disciplines as a continuum of knowledge will students understand of the role of science in their lives.

Movement in these directions requires change. Successful change in science education requires effective leadership of the science specialist. It is my sincere hope that this *Third Sourcebook for Science Supervisors* will help science supervisors become successful catalysts in their role of improving science education for the present and the future.

KENNETH RUSSELL ROY
NSSA PRESIDENT, 1987-88

Acknowledgements

This publication would not have been possible without the help of various individuals, including the many authors who submitted manuscripts. There has been a great demand to update the *Second Sourcebook for Science Supervisors*, published in 1976. This *Third Sourcebook* is different in both form and style.

The editors are grateful to NSSA's Editorial Board, which reviewed all the manuscripts for the *Sourcebook*: John C. Rosemergy, Richard J. Merrill, Mary B. Harbeck, Charles Butterfield, Ronald E. Charlton, Wayne R. Schade, and David Fagle.

Our appreciation to Phyllis Marcuccio, Shirley Watt, and Diana Holmes of NSTA Special Publications, for their many suggestions and their commitment to this endeavor. To Karen Jarrett, for the many hours she spent putting the manuscripts on our word processor, many thanks. To these individuals and to the many NSSA members and NSTA staff involved in the production of this publication, our gratitude and deep appreciation for their enthusiasm and interest.

LAMOINE L. MOTZ
GERRY M. MADRAZO, JR.
EDITORS

Introduction

The role of the science supervisor (science department head, science department chairperson, director of science, etc.) has changed dramatically since the *Second Sourcebook for Science Supervisors* was published in 1976. Professionals with responsibility for science supervision are involved in a myriad of time-consuming activities that need careful attention. Some science supervisors are expected to oversee science programs in a multitude of school buildings; others are expected to teach from two to five classes while carrying out the duties of supervisor and science specialist.

Many readers of this book will be new to the ranks of the science education specialist. This book will offer practical advice to both the novice and the experienced science supervisor. The editors, LaMoine Motz and Gerry Madrazo, have selected these manuscripts with the needs of science supervisors in mind. The articles within the pages of this *Sourcebook* have been written by and for science supervisors and science specialists.

As a science supervisor, you have chosen a field with many rewards and frustrations. The *Third Sourcebook for Science Supervisors* will help you handle the potential challenges of your position, and guide you in your pursuit of excellence in science supervision.

MERIK R. AARON
NSSA PAST-PRESIDENT, 1986-87

Table of

Contents

What Are the Trends, Directions, and Supervisory Skills for the 1990s?

New Directions in Science Education

1

PAUL DEHART HURD
STANFORD UNIVERSITY

In developed and developing countries throughout the world, efforts are being made to reconceptualize and modernize the teaching of science in schools. The central focus of these efforts is to make science and technology more useful to individuals so they can better direct their own lives and act responsibly in the civic affairs of their countries.

Certainly, a reform of science education is a priority on the national agenda for revitalizing the productive capacity of young people and the nation as a whole. Concerned citizens of the United States have begun to speak out, both locally and nationally, on the importance of reappraising and redirecting science education. They have articulated their concerns in a flood of national and state committee, panel, commission, and conference reports. The thrust of these reports is this: new social perspectives and a better selection of subject matter are essential if science education is to meet its cultural obligations.

A New Vision of Science Education

In recent years the growing impact of science and technology on societal and individual affairs has made both the goals and the subject matter of science teaching obsolete. The public now seeks a more viable contract between schooling and society, one in which science education is more closely tied to human affairs and social progress.

The past ten years have clearly shown that our nation is entering a new era. No period in history has been subject to more rapid change, and the tempo continues to increase as advances in science and technology change our culture, our economy, and our individual lives. Along with this change, the nation's perspective regarding the place of science and technology in today's society and the work place has also shifted. The situation is exacerbated by emerging changes in the image, ethos, and culture of science. While these are conditions that arose outside the schools, they are conditions to which schooling must adapt.

The perceived "crisis" in school science is an indictment of educators for their failure to respond to the cultural changes that beset us. The aims of traditional science education, the choice of subject matter, the context of the curriculum, and modes of instruction are now viewed as historically bound and too narrow in concept to provide an understanding either of modern science and technology or our culture. A new vision of what an education in science should mean is demanded.

Such national reports as *The Padeia Proposal* (1982) and *A Nation at Risk* (1983) criticize the content of present science curricula as remote from human needs and social benefits, reflecting the concern that science is alien and separate from individual and public interests. This traditional curriculum is seen as producing students barely knowledgeable about the role of science and technology in their individual lives and in the progress of society. Our task as science supervisors is to evolve a comprehensive reconceptualization and reorganization of school science that translates into and helps develop human capacities for dealing with the realities of change, lifelong learning, and civic responsibility. This requires a curriculum based on interrelationships between human beings, natural phenomena, advancements in science and technology, and the quality of life.

The New Face of Science

The first step in planning a reform of school science is to examine the nature of the multidimensional changes in science, technology, and society that generated the perceived crisis in science teaching. We begin by exploring the culture and image of modern science. Science and technology are no longer regarded as distinct enterprises: they operate as an integrated system. The "intelligent" instruments that engineers develop make it possible for scientists to ask new and more penetrating questions of nature, questions that were previously unanswerable because of the lack of appropriate technology. For example, the recent invention of the scanning tunneling microscope allows cells to be observed at the atomic level and reveals how atoms are bonded. At present, it is our best hope for discovering why a cell becomes cancerous. The time may not be long in coming before we have a new science of atomic biology.

Modern science has changed in other ways. No longer is it possible to generalize any one investigative procedure as the "scientific method." Research methods in ecology, high energy physics, laser chemistry, seismology, and human behavior have little in common with each other, except the enthusiasm and dedication of the researchers. In addition, most research today is done by a team: team managers, researchers, technicians, and facilitators work together, each providing different perspectives on a problem. Their success depends as much on such social qualities as the ability to communicate and cooperate as it does on the science background of each investigator.

Scientific research today is increasingly oriented toward problems of human and national welfare rather than focused specifically on advancing a scientific discipline. Thomas Kuhn, the eminent philosopher of science, notes that today both progress in science and the shaping of new fields result as much from social, economic, and institutional forces as they do from reason and observation. Science both stimulates and reflects the course of social and economic development. This view of the image and process of science has *not* been expressed in previous curriculum reforms. School science courses have traditionally been divided along the lines of biology, chemistry, physics, and earth science, each modeled after parent research disciplines characteristic of the early nineteenth century. During the 1960s, the science education reform movement treated each science subject as a wholly autonomous discipline, limited to its own concerns and research interests.

Science disciplines have since been fractionated to the extent that it now takes nearly 70,000 journals to report the results of research in the diverse fields of science and technology: all are necessary to make it possible for individual researchers to communicate with their equally isolated cohorts.

Not only have biology, chemistry, physics, and earth science been fractionated, they have also been hybridized into new sciences such as biochemistry, biophysics, molecular biology, geobiochemistry, biotechnology, and many more. Today, distinctions between one scientific effort and another are identified by the problem being researched, for example, cognition, monoclonal antibodies, nuclear quarks, fiber optics, thin films, laser surgery, or protein structure. To study each of these topics, many of what used to be discrete disciplines are melded in the research effort. School science courses, however, continue to be organized into discrete disciplines that no longer have meaning in modern science. What we seek is a science curriculum framework that integrates the separate science disciplines and their interconnections with human affairs.

The New Face of Technology

One of the most frequent recommendations made in the national reports is that technology concepts and reasoning processes be integrated into the science curriculum if science education is to meet the needs of our society. Modern technology is recognized as a sociotechnical svstem that enables people to extend their adaptive capacities both qualitatively and quantitatively. It is the *process* by which information from science, engineering, and the social fields is used to change our environment or some aspect of human existence. The thinking processes typical of technological problems closely parallel those that individuals use to solve personal and social problems occurring in everyday life.

As a teaching goal, scientific and technological literacy translates into the ability of a student to interpret scientific achievements and deficiencies in terms of the human and social forces that generate and sustain them. Students who are not literate in terms of the interaction of science, technology, and society will be isolated within the society that surrounds them. Typically, curriculum reformers of the 1960s purged from science textbooks all reference to technology as irrelevant to scientific endeavors and thus separated the subject matter from the affairs of the individual.

When science and technology are related to social and human welfare, issues of values and ethics arise: science and technology are never value-free nor ethically neutral either for scientists or citizens. A serious criticism of science teaching today is that students complete courses with a paucity of those value and ethical concepts essential for responsible decision making and for providing positive directions for learning and living. But teaching students a particular set of values is *not* the objective; instead, we must give students the opportunity to integrate knowledge of science and technology into the making of informed judgments.

In traditional science curricula, values, if dealt with at all, are *internal* to scientific disciplines emphasizing intellectual honesty, priority in recognition for a discovery, and the importance of peer judgments. In the current reform movement, value considerations are *external* to the discipline as they relate to thos individual and social pursuits with a base in science or technology.

A major criticism of the subject matter found in most science courses is that it has little meaning for life outside of school. The new goal is to make it possible for students to perceive school learning and life experience as parts of a continuum. Hopefully, when students ask: "What good is all of this to me?" they will now get a more sensible response than: "You will need to know this in the next grade, or in college."

Teaching Students to Think

What is desired is a curriculum affording students more opportunities to identify with the subject matter by exploring problems, processing information, formulating options, and making informed judgments on individual and real-world concerns. Students are expected to go beyond technical knowledge and isolated facts and consider the relationships of human experience and the purposes and values therein, the social, economic, political, and humanistic variables. The over-all purpose is to have students take a more active role in learning, in contrast to the passive learning and memorization that characterizes far too many traditional science classes.

A major criticism of schooling at all levels is that students do not learn to reason and think critically. A problem-oriented societal context for science courses provides the framework essential for the development of such intellectual skills as problem solving, decision making, and the synthesis of knowledge. These are among the intellectual skills required for effective participation in an "information age"—the age we are now entering. Today, throughout the entire world, the common economic denominator is knowledge. This is the first era in all of history in which knowledge ranks above natural resources or industrial products as a nation's chief economic resource. Knowledge and its utilization is now the measure of any country's competitive position in the world market. The same condition is true for the individual: A student's ability to enter and advance in the new labor market increasingly depends upon his or her ability to acquire, process, communicate, and apply information.

Over the past twenty years, science courses have emphasized students' acquisition of intellectual skills presumed to be those characteristic of the scientists' search for new knowledge. While it is important for students to understand how new knowledge is discovered through inquiry, they must also know how to make optimal use of what they have learned: knowing, alone, is not sufficient. A major distinction between the science reform movement in the 1960s and 1970s and its current phase is the emphasis upon knowledge *utilization*. In order to use information effectively, students must acquire a range of intellectual concepts that include those of risk, optimization, probability, trade-offs, variables, decision making, diversity, problem solving, approximation, compromise, maximizing, and heuristics. These critical thinking skills are not likely to be acquired unless the science curriculum contains problems, case studies, or issues which employ these concepts.

Toward a New Science Curriculum

Science courses have traditionally focused on the past only in terms of what scientists have learned, and there they stop. Today's technological society requires that citizens look forward. We need a curriculum that integrates time and events that consider the student's life today and tomorrow. The curriculum should develop an awareness on the part of the student that both life and knowledge represent a continuum, ongoing processes that create the future from the present. As students deal with problems of their environment, nuclear energy, health, and artificial intelligence, they are exploring their own lives: they are both part of the problem and part of the solution. The future is a product of the decisions we make today, as is the adaptive capacity of the individual. A future-oriented curriculum is not for the purpose of predicting the future, but of shaping it.

A sizable portion of laboratory work would be centered on science/technology-based individual and social problems for which students need to locate, assemble, and organize information, and form a logical interpretation of its meaning. The most desirable problems for investigation are those in which students have a stake in the outcome, such as nutrition, chemical safety, space exploration, human ecosystems, drugs, population growth, safety, the quality of life, and others. From this perspective, laboratory problems conclude with a proposed action toward what should be done to change, improve, correct, prevent, or better plan.

A question frequently raised is whether the proposed changes in science education are intended for all students or only for the college-bound. The answer: the education of all students, without exception, must incorporate a science curriculum designed for life and citizenship in a democracy strongly influenced by achievements in science and technology. Differences in the cultural backgrounds of students, in learning styles, and in intellectual ability are to be accommodated in the instructional process and not by the curriculum.

In the 1960s science curricula were frequently modified by adding minicourses on assorted topics to accommodate the so-called "special student." The present view is that there should be a core or common curriculum in science for all students and required at every grade level from kindergarten through at least grade ten. No students are to be deprived of the opportunity to know their own culture and to learn what human enterprise can accomplish.

What I have sought to identify in this essay is something of the thrust and flavor of the proposed reform of science education in the United States, a reform projected to carry both the individual and the nation forward as we enter a new era.

References

Adler, M. J. (1982). *The Paideia proposal: An educational manifesto.* New York: Macmillan Publishing Company.

National Governors' Association Center For Policy Research and Analysis. (1986). *Time for results: The Governors' 1991 report on education.* Washington, DC: National Governors' Association.

Boyer, E. L. (1983). *High school: A report on secondary education in America.* The Carnegie Foundation for the Advancement of Teaching. New York: Harper and Row.

Business-Higher Education Forum. (1983). *America's competitive challenge: The need for a national response.* Washington, DC: American Council on Education.

Committee for Economic Development. (1985). *Investing in our children.* New York: Committee for Economic Development.

Doyle, D. P., & Hurtle, T. W. (1985). *Excellence in educationThe states take charge.* Washington, DC: American Enterprise Institute for Public Policy Research.

Educational Equality Project. (1986). *Academic preparation in science.* New York: College Entrance Examination Board.

Hurd, Paul DeH. (1984). *Reforming science education: The search for a new vision.* Washington, DC: Council for Basic Education.

National Academy of Sciences, National Academy of Engineering. (1982). *Science and mathematics in schools.* Washington, DC: National Academy Press.

National Commission on Excellence in Education. (1983). *A nation at risk.* Washington, DC: U.S. Government Printing Office.

National Science Board Commission on Precollege Education in Mathematics, Science, and Technology. (1983). *Educating Americans for the 21st Century.* Washington, DC: National Science Foundation.

National Science Foundation. (1980). *What are the needs in precollege science, mathematics, and social science education? Views from the field.* Washington, DC: National Science Foundation.

National Science Teachers Association (1983). *Focus on excellence.* (A monograph series). Washington, DC: Author.

Panel on Secondary School Education for the Changing Workplace. (1984). *High schools and the changing workplace: The employer's view.* Washington, DC: National Academy Press.

Report of the Twentieth Century Fund Task Force on Federal Elementary and Secondary Education Policy. (1983). *Making the grade.* New York: The Twentieth Century Fund.

Scientific literacy. (1983, Spring). *Daedalus, 112(2).*

Shane, H. G. (1981). *A study of curriculum content for the future.* New York: College Entrance Examination Board.

Task Force on Education for Economic Growth. (1983). *Action for excellence.* Denver: Education Commission of the States.

Paul DeHart Hurd has had a 50-year career as a classroom teacher and a university professor in science education. He is the author of seven books in science education and close to 200 articles. His current research is focused on the conceptual history of science education and contemporary efforts to restructure science teaching.

Supervisory Skills for the 1990s

2

WAYNE M. WORNER
VIRGINIA TECH UNIVERSITY

The role and function of science supervisors in the 1990s will be shaped in significant ways by several of the events and trends that have dominated education during this decade. The series of reports produced in the last 10 years by special commissions, professional associations, public and private agencies, and other special interest groups heightened public concern for quality education. This concern, which reached its apex in 1983-84, is still strong, and has spawned a second generation of reports. The changing demographics of public schools will also significantly influence the way in which science supervisors go about their duties. The changing profile of personnel available to teach our young people and the changing population in our classrooms will greatly challenge our ingenuity and imaginations.

A number of changes in our demographics and in our society's needs make predicting the future a risky business. Several trends suggest modifications in public schooling that the successful science supervisor will have to address.

Impact of the Reform Movement

The first round of the current reform movement focused primarily on the perceived deficiencies of public secondary schools in America and recommended fundamental changes in curriculum, course requirements, and graduation standards, all of which were linked to improving America's competitive position in a global economy. State and local boards of education, responsible for directing and monitoring public schooling, cooperated to establish significantly higher expectations for schools and the students who attend them. Moreover, in cooperation with (and sometimes stimulated by) state legislators, governors, and local fiscal authorities, a substantial increase in resources was provided to support those higher expectations.

In addition, the initiatives stimulated by such early reports as the National Commission's report, *A Nation at Risk* (1983); Education Commission of the States' *Action for Excel-*

lence (1983); Boyer's Carnegie-sponsored report on secondary education in America entitled *High School* (1983); Goodlad's extensive research in *A Place Called School* (1984); and dozens of other major efforts focused primarily on public schools. These were followed by a second round of studies targeting a wider range of institutions and agencies associated with public education. The most comprehensive of this second group is probably *Time for Results: The Governors' 1991 Report on Education* (1986). While it provides recommendations across seven broad areas, at least two of the task forces made recommendations which could significantly alter the role of the science supervisor in the 1990s.

Reports prepared by the Carnegie-sponsored Task Force on Teaching as a Profession, *A Nation Prepared: Teachers for the 21st Century* (1986) and *Tomorrow's Teachers*, produced by the Holmes Group (1986), a coalition of teacher education deans representing approximately 75 percent of the nation's leading research universities, will also affect the role of the science supervisor and redefine the skills needed for success in the 1990s.

While *A Nation Prepared*, like many of the earlier reports, acknowledges serious shortages of personnel in critical areas, including science, the Governors' Report makes several suggestions for dealing with these shortages, including significantly changing the way teachers are prepared, utilizing personnel from business and industry to assist in areas of shortage, and modifying school governance systems to accord teachers a more significant decision-making role in curriculum and other areas that affect the classroom environment.

Demographic Impacts

When we add the significant demographic realities affecting the nation's schools from now through the year 2000 to the debate regarding the fundamental purposes of schooling and the governance of schools, we define an environment that challenges the imaginations of even the most adaptable.

What are those demographics which will affect science programs and thus require the attention of the science supervisors? First, there is an estimated 25 percent shortage of personnel to staff *current* programs. Secondly, a projected 50 percent of all currently employed science teachers will be lost through retirement, disillusionment, better opportunities, or other reasons by 1995. Thirdly, current reports (for example, *Time for Results*, 1986; Williams, 1987) indicate that science course enrollments of secondary students have increased by nearly a third, the result of higher graduation requirements and/or higher collegiate admission standards. How serious are these problems? What is being done? Unfortunately, not enough, and for several reasons. The impact of the convergence of these phenomena has been masked by at least four offsetting factors:

- a slight upturn in students completing teacher certification programs
- considerable softening of the certification requirements in a number of states, providing access to the teaching profession by graduates in science fields where other positions are not readily available (mostly biology and geology)
- some cooperation between business and industry to provide instruction in critical but understaffed areas (primarily physics)
- a decline in the total enrollment of secondary students nationwide from approximately 4 million in 1982 to 3 million in 1988

As a result, the number of science teachers actually required in 1988 for many schools *is less* than the number required two or three years ago, despite the number of teachers leaving the profession. As a consequence, the conditions provide a reprieve for planning strategies to prevent a major staffing crisis. Unfortunately, there is little evidence that much is now being done to avoid that crisis.

Who Has Control?

The push and pull for control of the direction and substance of public education will continue to affect the work of science supervisors. While the enormous influence of the federal government in shaping curriculum and training teachers has dissipated, state school boards and state departments of education, stimulated by sometimes over-zealous legislators and governors, dramatically influence curriculum and delivery systems through the imposition of accountability procedures. These procedures have the expressed purpose of improving the quality of education. To date, the results of these efforts have not always fulfilled their intentions. The inherent difficulty in legislating quality has nullified efforts to effectively regulate school improvement. This means that science supervisors will need to take a more active role in focusing and directing the teaching of science. Supervisors must work with their state departments of education to develop monitoring and evaluation instruments to measure the school improvement. In states where school districts design their own systems for measuring effectiveness (usually with the approval of state agencies), supervisors will need to know how to develop evaluation systems which correlate local instructional programming with state-mandated instructional outcomes. Curriculum alignment with accountability measures will be essential for continued public support. The danger of stress on accountability, one that supervisors must guard carefully, is that measurement tools must be based on content and process instruction, not the reverse.

Impact of Testing

"Americans are preoccupied with the Dow-Jones," said Michael Kirst, Professor of Policy Studies at Stanford University, when explaining the emphasis placed on test results as an indicator of school quality. For better or worse, individual schools and school systems are compared according to SAT scores, number of merit finalists, percentages of students going on to college, comprehensive scores on achievement test batteries, and a host of other numerical indicators. Rarely is there public acknowledgement or even consideration of equally important ability/achievement comparisons or indicators of success: Data regarding students graduating with certified work skills, positive self-concepts, predispositions to lifelong learning, and other criterion-referenced indicators tend to receive short shrift in the metric of quality.

Thus, the challenges facing the supervisor of science include:

- the pragmatic problem of assessing curriculum alignment, ensuring that program evaluation matches curriculum purpose *and* content
- a problem of political importance: how to achieve good test scores without compromising the development of those goals not being measured
- the challenge of designing instructional programs appropriate to the needs of an increasingly diverse student body, needs which may not be considered in accountability instruments developed by external groups

Impact of the Effective Schools Research

Over the past five years, educators have been inundated with research findings advocating implementation of strategies generally believed to improve schools. Two fundamental assumptions underlying the effective schools movement should give pause to science supervisors. The first is that effective schools are defined as those in which students score well on standardized achievement tests. The second assumption is that identified correlates are causal. While the movement has been influential in renewing the faith that schools can and do make a difference in student success, much of the research simply reinforces what we have known intuitively about the conditions and practices underlying effective schooling.

Science supervisors will need to review this research and determine ways in which it can be helpful to science teachers. Special attention should be paid to the fundamental differences between effective school approaches that are top-down efforts with prescribed goals and processes, and the more recent calls for site-based initiatives. Obviously, the role of the science supervisor will vary dramatically according to the approach taken in the school district. In either case, the supervisor will have to sharpen his or her skills in group process and facilitation, in addition to the planning and evaluation skills appropriate to designing new programs. Teachers in all programs will be expected to develop strategies designed to meet school system or school building goals not traditionally viewed as subject area concerns. Improving school climate, writing across the curriculum, and helping develop students' self-concepts are all examples of activities science teachers might be asked to integrate into their instructional programs.

Systems Versus Schools

In most school systems large enough to employ subject matter supervisors, there is growing pressure to centralize the decisions affecting programs. The forces driving centralized decision making include:

- concerns about equity and consistency across schools (horizontal)
- concerns about articulation between levels of schools (vertical)
- need for central reporting to respond to increased demands for information from state and other data collecting agencies
- perceived economy of scale and efficiency considerations

Private sector business reports (Peters & Watermann, 1983) and education writers (Goodlad, 1984, for example) argue that effectiveness and excellence are more likely to occur if priorities and implementation decisions are reached at the plant or site level. As school districts examine the advantages and disadvantages of centralized versus decentralized decision making, they will likely arrive at some hybrid management style attempting to incorporate the benefits of both. Whatever that structure may be, it will require the redefinition of relationships between and among supervisors and building level administrators. These shifts may well bring revisions in the way supervisors influence budget and personnel decisions as well. Supervisors must review that literature and be familiar with the concepts underlying the movement toward site-based program management.

Using the Education Research Findings

The processes of teaching and learning have been closely examined over the past 10 years. Much more needs to be done, especially with regard to those processes commonly employed by science teachers.

One barrier to the use of the new research is the continuing inability of the American public generally and educators specifically to agree upon the mission and purpose of schooling. One consequence is that easily measurable outcomes (e.g., test scores) have emerged as the predominant evaluation strategy, while concept development and process skills, so important to the science program (but more difficult to measure), have received less attention than in earlier years.

Many of the structured teaching models receiving attention across the country (TESA, Hunter, Mastery Learning, etc.) are designed for a classroom environment in which a fairly standard lesson design approach, rather than inquiry or hypothesis generating activities, is assumed. It is not that these models cannot accommodate these latter approaches (the proponents have been careful to point out the adjustments necessary when applied to unique instructional settings); rather, the problem lies in the inappropriate use of evaluation techniques based upon incomplete understanding of the models and their robustness.

Science supervisors should expand their knowledge of contemporary research in teaching and learning and make sure that those responsible for evaluating personnel and programs in science make appropriate adjustments to evaluation systems associated with the new teaching models.

Evaluation and Supervision

Perhaps the most significant changes in the role of science supervisors will result from major changes in the process of supervision and evaluation at the local school district level.

Partly as a result of the pressure to enhance teaching as a profession, much attention has been given to merit and career ladder plans designed to differentiate pay on the basis of performance. This focus on rewarding competence has reversed a twenty-year trend in supervision and evaluation that seemed to focus on documenting incompetence. In the process of examining alternative compensation approaches, the emphasis has shifted from supervision for the purpose of personnel decisions (documentation) to supervision for the purpose of improving instruction. Moreover, there is clear evidence that the practice of supervision for instructional improvement is rapidly moving from rhetoric to reality.

While concerns remain about the need to remove incompetent teachers from the classrooms, those actions are viewed as exceptional rather than focal to the supervisory process. Increasingly, competence is assumed, and with it comes the assumption that most teachers believe they can and want to teach better. Job targets, clinical supervision procedures, personalized professional development plans, major expenditures for staff development, and peer evaluation systems are tools used frequently today.

Supervisors must develop the skills necessary to participate in these processes in their role as resource personnel or instructional specialists for the school district. At the same time, supervisors need to be prepared to serve on remedial assistance teams designed to provide intensive supervision and assistance to teachers identified as operating at minimal levels. Special expertise in diagnosis and prescription relating to instructional effectiveness will be even more important than in the past. Planning and conducting workshops that overcome content deficiencies as they aid instructional technique will also challenge the supervisor in the 1990s.

The skills required of science supervisors in the 1990s will be determined in large measure by the same issues that currently affect the environment, focus, and operation of America's schools.

The successful science supervisor in the 1990s will need to remain flexible and alert to the sensitive environment within which we work. Among those skills most critical to professional survival in the coming decade will be:

- the ability to recruit and retain high quality teachers
- the ability to work with teachers in both a collegial and supervisory relationship
- the skills to work with teachers as they become much more involved in shaping the environments in which they operate
- the knowledge and skills to design and conduct staff development programs for teachers with inadequate or outdated preparation
- the knowledge and skills necessary to appropriately adapt science curriculum for "at-risk" or low-ability students with nominal interest in science
- the skills and knowledge required to work with and apply the new technologies (satellites, laser disks, computer modeling, etc.) to enhance student learning
- the knowledge to provide specialized content information
- the knowledge and skills required to review and align local curriculum with standardized tests used to evaluate school programs
- the ability to review and select information relevant and appropriate to local school initiatives from the effective schools literature and other research

- the ability to work with teachers and administrators at the building level to address specific needs arising out of sitebased priority setting activities
- the political skills necessary to affect statewide curriculum development and monitoring systems
- the ability to recognize the changing role expectations of supervisors in new systems of teacher supervision and appraisal

With these skills the science supervisor in the 1990s should be in a position to continue to provide the strong leadership necessary to achieve the goal outlined by the National Science Board Commission (1983) to make..." this country's elementary and secondary mathematics, science and technology education, the world's finest by 1995 ... without sacrificing the American birthright of personal choice, equity and opportunity."

References

Boyer, Ernest L. (1983). *High school: A report on secondary education in America.* The Carnegie Foundation for the Advancement of Teaching. New York: Harper and Row.

Carnegie Forum on Education and the Economy. (1986). *A nation prepared: Teachers for the 21st century.* (The report of the Task Force on teaching as a profession). Washington, DC: Author.

Feistritzer, C. Emily. (1983). *The conditions of teaching: A state by state analysis.* Princeton, NJ: Foundation for the Advancement of Teaching.

Goodlad John A. (1984). *A place called school.* New York: McGraw-Hill Book Company.

Hodgkinson, Harold L. (1985). *All one system: Demographics of education, kindergarten through graduate school.* Washington, DC: Institute for Educational Leadership, Inc.

The Holmes Group. (1986). *Tomorrow's teachers.* East Lansing, MI: Author.

Kirst, M. (1986, February). *The lessons from state education reform.* Speech made at the meeting of the American Association of School Administrators, San Francisco, CA.

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform.* Washington, DC: U.S. Government Printing Office.

National Governors' Association Center for Policy Research and Analysis. (1986). *Time for results: The Governors' 1991 report on education.* Washington, DC.: National Governors' Association.

Peters, Tho ·as J., & Waterman, Robert H., Jr. (1983). *In search of excellence.* New York: Warner Books.

Task Fcrce on Education for Economic Growth. (1983). *Action for excellence.* Denver: Education Commission of the States.

Williams, Thomas H. (1987). *Certified science and math teachers who are not teaching: Reforms in the conditions of teaching required to encourage them to return or enter teaching.* Doctoral dissertation, Virginia Tech, Blacksburg, VA.

Wayne Worner is a former chemistry teacher, principal, assistant superintendent for curriculum, and superintendent for schools in North Dakota. For the past two decades he has served as a department head and Professor of Administration at Virginia Tech. He has served as a consultant in program planning, evaluation, and policy development for local school systems and state agencies throughout the nation.

Fifty Years of Science Education, 1950–2000

3

ROBERT E. YAGER
THE UNIVERSITY OF IOWA

With the dropping of the atomic bomb on Hiroshima on August 6, 1945, America dramatically established its global scientific and technological supremacy. Science and technology suddenly became perceived as major forces in the international balance of power, in our daily lives, and as a threat to human survival—all developments for which we as a nation were ill-prepared.

In 1950, as an attempt to accommodate the new centrality of science and technology to our national goals, the National Science Foundation (NSF) was created as an independent government agency. While its major purpose was to provide direction and financial support for scientific research, science education was included as a directorate, underscoring the prevailing attitude toward the interrelationships of science education and the production of future scientists, engineers, and an informed citizenry.

In the mid-1950s, existing school science programs came under strong criticism from the scientific community: many felt that textbooks still focused on old science and technology; that many textbook authors were poorly qualified; and that students were learning inaccurate and out-of-date information. Jerrold Zacharias, a physicist at the Massachusetts Institute of Technology, led the calls for reform. In 1952 he convened the Physical Sciences Study Committee (PSSC), which described and outlined a new high school physics program.

The Soviet Union's exploits in space in 1957 suddenly focused public attention on science education. The launching of the Soviet Sputnik spurred major federal efforts to improve and to redirect science education. Threatened with the loss of scientific and technological superiority, the federal government significantly increased NSF funding for science education; the National Defense Education Act (NDEA), passed between 1958 and 1961, provided unprecedented funds for improving school science.

Funds were now available for curriculum development. The first in a long series of national projects was Zacharias' PSSC course, followed by courses in chemistry (Chem Study and CBA), biology (three BSCS versions), and earth science (ESCP). Later, programs for the elementary school (SAPA, SCIS, ESS, COPES, and others) and the middle/junior high school (ISCS, IPS, HSP and others) were funded. During a two-decade period, about a half-billion dollars was spent in the development of new materials for use in schools.

Science teacher improvement, especially in terms of increasing their subject matter competence, was a target for funding as well. The various institute programs proved extremely popular, since they recognized the importance of science teaching, provided for the costs of instruction, and, in many instances, provided further support via stipends and dependency allowances. In all, another half-billion dollars was spent for teacher education activities after Sputnik.

The NDEA funds were used to provide new instructional materials, local curriculum revision, and course development in K–12 schools. This funding also stimulated a broader view of school science, created awareness that science is an expensive undertaking, and encouraged partnerships with state officials and local leaders. The NDEA funding for science equaled that provided by NSF. With funding from schools, state agencies, and private corporations matched or supplemented NSF and NDEA initiatives, well over a billion dollars was spent on science education from 1957–77.

With inflation and the current extent of funding from a variety of sources, a billion-dollar figure does not seem extreme today; yet support at this level represented a major departure from traditional public education funding at the time. It was enough for many to refer to the late 1950s, the 1960s, and the early 1970s as a Golden Age for science education in this country.

But the 1970s brought new national concerns. The challenges of the 1960s followed the confidence and complacency of the 1950s, and brought about new successes in the space age. President Kennedy's goal of "putting a man on the moon and returning him safely to Earth" was realized. There were now new social concerns: U.S. involvement in Vietnam generated general disillusionment with many social institutions. The schools—perhaps for the first time in our national history—were not a source to which we could turn for solutions, but were perceived as a part of the problem itself. The funding and general support for education—including science education—was called into question. Many of the curriculum developments of the early 1970s came under attack, some charging that they were removed from "basic" science. Had the funding really led to improvement? Could the support for improved science materials and competent teachers actually have been misguided?

The criticism peaked in 1976 when all curriculum projects supported by federal funds were temporarily halted for examination and review. All funds supporting teacher education activities were suspended amidst charges that there had been no substantial improvement in science classrooms and teaching strategies. By 1976, public support for science education had dramatically shifted. Funds for special science education projects and classroom equipment and supplies began to disappear. It was announced that the Third Assessment of Science by the National Assessment of Educational Progress (NAEP) would be the last. There was greater interest in basic skills, including reading and mathematics; science was not considered basic and there was little support for further attempts to improve materials, curricula, and teachers.

The total NSF budget, including that for science education, did not decline in 1976. However, the funds that might earlier have supported school science were redirected to other levels, especially toward research and college science programs.

Three large status studies were funded in an attempt to answer the basic questions asked by political and educational leaders concerning the two decades of national support for science education. One of these studies was a review of all science education research between 1954 and 1975 (Helgeson, Blosser, and Howe, 1977). A second was a mammoth demographic study to assess enrollments, offerings, teachers, instructional materials, and other information that could be discerned via questionnaires for teachers, supervisors, administrators, state officials, and members of the public (Weiss, 1978). A third was a series of case studies by ethnographers (Stake and Easley, 1978). When the studies were completed in 1978, nearly three thousand pages of information were available—almost too much to be meaningful to the public or educational leaders. NSF funded nine professional organizations to read the status reports and to provide summary information for their members (NSF, 1979).

The Third Assessment of Science by NAEP became available to the public in 1978 as well. These data added another dimension: student achievement in and attitude toward science. This Third Assessment included an extensive series of affective items for the first time in the history of NAEP. The NSF-sponsored Project Synthesis then linked the NAEP information and the preliminary reports of the three NSF Status Studies.

The results of Project Synthesis were reported by the National Science Teachers Association (NSTA) in 1981 (Harms and Yager, 1981). Basic to the synthesis effort were four goal clusters developed by an expert panel. These goal clusters have since been widely used to extend thinking about programs and teaching beyond a single dimension—that related to the fundamental knowledge that traditionally governs science content and its organization. The four goal clusters from Project Synthesis are:

Goal Cluster I:

Science for Meeting Personal Needs. Science education should prepare individuals to use science for improving their own lives and for coping with an increasingly technological world.

Goal Cluster II:

Science for Resolving Societal Problems. Science education should produce informed citizens prepared to deal responsibly with science-related societal issues.

Goal Cluster III:

Science for Career Awareness. Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.

Goal Cluster IV:

Science as Preparation for Further Study. Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate for their needs.

As Project Synthesis was in progress, NSTA presented its position paper, "Science-Technology-Society: Science Education for the 1980s" (1982), which pointed to a new direction:

The goal of science education during the 1980s is to develop scientifically literate individuals who understand how science, technology, and society influence one another and who are able to use this knowledge in their everyday decision-making. Such individuals both appreciate the value of science and technology in society and understand their limitations.

The paper continued with a description of the competencies for which a K–12 science program should aim. An ideal science program will produce graduates who:

- use science concepts, process skills, and values in making responsible everyday decisions;
- understand how society influences science and technology as well as how science and technology influence society;
- understand that society controls science and technology through the allocation of resources;
- recognize the limitations as well as the usefulness of science and technology of advancing human welfare;
- know the major concepts, hypotheses, and theories of science and are able to use them;
- appreciate science and technology for the intellectual stimulus they provide;

- understand that the generation of scientific knowledge depends upon the inquiry process and upon conceptual theories;
- distinguish between scientific evidence and personal opinion;
- recognize the origin of science and understand that scientific knowledge is tentative, and subject to change as evidence accumulates;
- understand the applications of technology and the decisions entailed in the use of technology;
- have sufficient knowledge and experience to appreciate the worthiness of research and technological development;
- have a richer and more exciting view of the world as the result of science education; and
- know reliable sources of scientific and technological information and use these sources in the process of decision making.

The lengthy reassessment of priorities and programs which began in 1976 resulted in a major document to President Carter (NSF, 1980). The report called for specific correctives for continued support at the national level. However, the report was completed in the midst of the presidential election which resulted in President Carter's defeat. President Reagan dismissed the NSF-Department of Education report and announced that a perceived crisis in science education did not exist. He attempted to eliminate the science education directorate at NSF and to reduce the power and influence of Department of Education. He succeeded in reducing science education at NSF to support for college faculty improvement and graduate student fellowships in the basic sciences.

The National Science Board (the governing board for NSF) appointed a Commission on Pre-college Education in Mathematics, Science, and Technology. The 20-member commission was reminiscent of the early 1970s when the public was called to judge the previous NSF initiatives in terms of curricular efforts and teacher education activities. This Commission was given a $700,000 budget and 18 months to study science education in the United States and report on the appropriate federal role in its improvement. The committee's report, ***Educating Americans for the 21st Century***, (NSF, 1983) was aimed at the American people as well as the National Science Board, and was at once heralded as a blueprint for action: It called for the expenditure of over one and a half billion dollars for 1984–85. The report included recommendations from Project Synthesis, and included model programs from the Search for Excellence in Science Education (SESE), an ongoing NSTA project designed to highlight exemplary science education programs around the nation.

The Science Education Directorate has been revitalized, a new director appointed, new organization approved, and a growing professional staff is at work. A budget of nearly $140 million has been used to support programs designed to enhance science teaching, to produce model materials, and to study the impact of such efforts.

Other societal forces are at work to improve science education. The support for such improvement efforts is greater than it has ever been in the past. Recent polls (Yankelovich, 1984; Yager, 1985; Yager and Fenick, 1986; Yager and Yager, 1985) illustrate the changes in public support. Governors' conferences are considering science education and proposing correctives at the state level as never before. Industry is also playing a greater role than in the past, proposing and funding correctives. And private foundations have recently funded more science education projects than they ever have previously.

We are now faced with the task of interpreting and resolving the differences with respect to the goals and correctives proposed for science education. The problem now most commonly used to justify the need for improved science in our schools is the international economic imbalance and the seeming superiority of the Japanese and other industrialized nations in the market place. The U.S. is no longer unchallenged in the international arena, and many again point to our national schooling as the reason. Industry is unhappy with the academic preparation of their new employees; the military wants new recruits to have basic education and technological skills; the public looks to the schools to produce graduates who will help America compete better internationally. Such immediate concerns ignore the breadth of the goal clusters advanced by the Project Synthesis researchers and fail to consider the procedures needed to accomplish scientific literacy as described by NSTA.

The basic question is this: Should science educators be producing citizens who demonstrate a rote mastery of certain information that many believe would make them better prepared for industry, the military, vocational study, and college programs? There is a basic assumption that if more people are forced to spend more time acquiring basic science information for more years, many national problems will disappear. Unfortunately, there is no evidence that simply increasing the dose will cure our ills. Yet there have been several hundred laws passed in the last few years to increase such things as time-on-task, the number of years of science required for graduation, and the number of college science courses that teachers must complete. We continue with such assumptions that more is better; that scientists are the best judges of what science is appropriate for all; that college experiences and subject matter preparation produce more effective science teachers; that knowledge is a necessary precursor for exploring and acting; that appropriate measures of success are in terms of information/concept mastery only.

The NSF seems anxious to find more scientists who can help with improvements in schools. The American Association for the Advancement of Science has accepted several million dollars from the Carnegie Foundation on the premise that leading scientists can and should define just what science all persons should know. However, it seems clear to many that most current learning in traditional settings (classrooms to laboratories) is not learning at all. A common concern lies with the naive theories that most high school graduates have about basic science. Champagne and Klopfer (1984), for example, have reported that many university physics majors (among the most successful high school graduates and the best performers in high school science) still hold basic scientific misconceptions and cannot relate what they seem to know to real-world examples.

Many are heralding the Science/Technology/Society (S/T/S) efforts as a solution to current problems. These efforts are attempts to provide structure and meaning to the NSTA Position Statement for the 1980s. Rustum Roy, the director of a current NSF project, Science through Science/Technology/Society, has called S/T/S the glue that holds science together for most, the soil from which science can grow from most, and the dominant trend in science education for the next decade and longer (Roy, 1983, 1985a, and 1985b). To some, S/T/S appears to be a fad, the focus in vogue, the latest educational jargon. It may be all three if it is used as merely another term for doing the same thing in classrooms across the nation.

But S/T/S can be a major organizer for school science. Recommendations passed unanimously by a task force for the National School Board Commission called for the following school science structure:

- *K–6*. An integrated, hands-on approach is needed, which focuses on the relationships between humans and the total environment. Problem solving must be emphasized, including acquisition and analysis of data.

- *Grades 7–8*. Two primary emphases should be made. The first is on human science, including human biology and personal health. The second concerns the development of quantitative skills in science. Computer-based experiences should be used appropriately to assist in the development of quantitative skills that will be needed for more complex, applied problem solving in grades 9–10.

• *Grades 9–10.* A two-year sequence, required for all students, would address the interrelationships of science, technology, and society. This course emphasizes problem solving and scientific reasoning as applied to real-world problems. It integrates knowledge and methods from physics, biology, earth science, chemistry, and applied mathematics. The rationale for placing this sequence at the 9–10 grade level is that the students need to have acquired the developmental math and problem-solving skills prerequisite to the complex kinds of problem-solving tasks required in this course. This is a much higher level kind of course than is generally recognized as a "general science" course for non-science students.

• *Grades 11–12.* One- and two-semester courses in physics, biology, chemistry, and earth science are provided at this level for students who wish to go on to further academic study and science-related careers. These are not Advanced Placement courses and are not meant to replicate college-level courses. These courses build upon and assume as prerequisites the skills and knowledge of the various science disciplines that students will acquire in the Science, Technology, and Society course in grades 9–10. Although grades 11 and 12 were to include the college preparatory courses (those Fensham suggests should be in a "vocational" department [Fensham, 1986]), the Task Force recommended an additional S/T/S course or courses for the general student not needing discipline courses for college entrance.

Some have tried to define science and S/T/S in more meaningful ways. Science makes more sense to most (and perhaps is more appropriate for all) if a definition like George Gaylord Simpson's is used. He defines science thus:

> *Science is an exploration of the material universe in order to seek orderly explanations (generalizable knowledge) of the objects and events encountered:* but these explanations must be testable. *(1963, p. 81.)*

Simpson's definition emphasizes the importance of personal experience—the acts of exploring, explaining, and testing. These acts depict science as a human enterprise available to all as opposed to a few, and available now as opposed to later, after mastering a textbook or a specialized vocabulary.

S/T/S begins with the student: his or her experience base, questions, and curiosities. It builds on what is known; it provides experiences that can be analyzed and used. It offers methods for finding the answers to questions, devising tests, and explaining phenomena in the student's world. In a sense, the knowledge gained is derived; it is sought out. It is not a prerequisite to learning; rather, it is the result.

S/T/S programs often include the following features:

- identification of problem with local interest and impact
- use of local resources (human and material) to locate information that can be used in problem resolution
- active student involvement in seeking information
- science teaching that goes beyond the class period, the classroom, and the school
- a focus on personal (i.e. student) impact
- a view that science content is not something that exists for student mastery simply because it is recorded in print
- an approach to process skills that will not "glamorize" the skills of practicing scientists
- a focus on career awareness in science and technology
- an emphasis on citizenship as students attempt to resolve the issues they have identified
- visibility of science study in both school and community
- encouragement for students to experience science
- a focus on the future and the role science will play

What will the 1990s bring in science education? Will those who argue that scientists can and should define the appropriate general science education content prevail? Will those who argue that standard achievement measures do identify the major outcomes from a science course for all people succeed? Will those who argue that basic science is the information recorded in textbooks win the argument? Will we proceed with measuring the mastery of specific concepts? Will we ignore the need to help students to act, to use knowledge, to make well-informed decisions? Much will depend upoupon the outcome of these debates. These decisions will plot the course for our schools, our children, and the future.

References

Champagne, A., & Klopfer, L. (1984). Research in science education: The cognitive psychology perspective. In D. Holdzkom & P. B. Lutz (Eds.), *Research within reach: Science education.* Washington, DC:National Science Teachers Association..

Fensham, P. J. (1986, December/January). Science for all. *Educational Leadership, 44* (4), 18–23.

Harms, N. C., & Yager, R. E. (Eds.) (1981). *What research says to the science teacher. (Vol. 3).* Washington, DC: National Science Teachers Association.

Helgeson, S. L., Blosser, P. E., & Howe, R. W. (1977). *The status of pre-college science, mathematics, and social science education: 1955–75.* Columbus, OH: Center for Science and Mathematics Education, The Ohio State University.

National Science Board Commission on Precollege Education in Mathematics, Science, and Technology. (1983). *Educating Americans for the 21st century.* Washington, DC: National Science Foundation.

National Science Foundation. (1979). *What are the needs in pre-college science, mathematics, and social science education? Views from the field.* Washington, DC: Author.

National Science Foundation. (1980). *Science and engineering education for the 1980s and beyond.* Washington, DC: Author.

National Science Teachers Association. (1982). *Science-technology-society: Science education for the 1980s.* (NSTA position statement). (Available from the National Science Teachers Association, 1742 Connecticut Avenue, NW, Washington, DC, 20009.)

Roy, R. (1983, May 19). Math and science education: Glue not included. *The Christian Science Monitor*, pp. 36–37.

Roy, R. (1985a, Winter/Spring). Bright vision/impossible dream. *SSTS Reporter*, 1–2.

Roy, R. (1985b). The science/technology/society connection. *Curriculum Review, 24*(3), 13–16.

Simpson, G. G. (1963). Biology, the nature of science. *Science, 139* (3550), 81–88.

Stake, R. E. & Easley, J. (1978). *Case studies in science education.* Urbana, IL: Center for Instructional Research and Curriculum Evaluation, University of Illinois.

Weiss, I. R. (1978). *Report of the 1977 national survey of science, mathematics, and social studies education: Center for educational research and evaluation.* Washington, DC: U.S. Government Printing Office.

Yager, R. E. (1985). The attitudes of the public toward science and science education. *Iowa Science Teachers Journal, 22*(2), 8–13.

Yager, R. E. & Penick, J. E. (1986). Perceptions of four age groups toward science classes, teachers, and the value of science. *Science Education, 70*(4), 355–363.

Yager, R. E., & Yager, S. O. (1985). Changes in perceptions of science for third, seventh, and eleventh grade students. *Journal of Research in Science Teaching, 22*(4), 347–358.

Yankelovich, D. (1984). Science and the public process: Why the gap must close. *Issues in Science and Technology, 1*(1), 6–12.

Robert Yager initiated many projects in science education at the University of Iowa over the past 32 years. He has published over 300 articles, directed over 100 NSF programs, and chaired 75 Ph.D studies. He has served as president of NSTA and five other national science organizations.

Science Education: A Framework for Decision-Makers

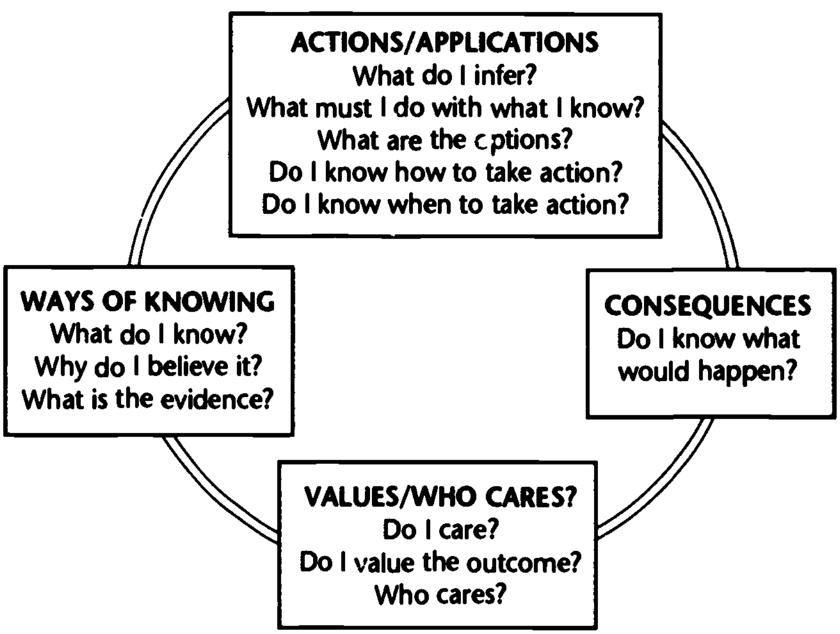
4

MARY BUDD ROWE
UNIVERSITY OF FLORIDA

During periods of perceived crisis, national debate in this country inevitably focuses on the purposes and content of science education, on how it is conducted, and who has access to it. We are now entering such a debate, if in fact it has not already started. Part of the debate centers around what levels of government should be involved and in what ways; in other words, given that an acceptable set of recommendations will eventually emerge, who will pay for the effort to revitalize science education? Legislators, school board members, textbook and test writers and their publishers, school administrators, technical experts such as scientists and engineers, and curriculum supervisors—all are influential in setting science and mathematics education policies. What they need is a frame of reference within which to evaluate recommendations, plans, and policies. In this paper, I propose such a frame of reference. I use it to evaluate some of the current controversies concerning what ought to be done to improve the quality and appropriateness of science instruction, and conclude with some recommendations for action.

According to the proposed paradigm, a full science program consists of four interdependent parts: Ways of Knowing, Actions/Applications, Consequences, and Values (Figure 1).

Figure 1. Four Components of a Full Science Program



This article first appeared in *Scientific Literacy* (Spring, 1983), issued as Volume 112, Number 2 of *Daedalus*, Journal of the American Academy of Arts and Sciences, Cambridge, MA. Reprinted by permission.

Using these components, we can examine science curricula, texts, instruction in classrooms, and even standardized tests to see whether all four are present. When we do, we usually discover that three of the four—implications for action, prediction of consequences, and the analysis of value—are either missing entirely or minimally treated at the elementary or secondary level. Yet these components are precisely what are of greatest interest to the majority of students. Even then, only a portion of the questions under the heading "Ways of Knowing" receives substantial attention in texts, tests, or instruction, with most consideration given to what we are supposed to know and very little to why we believe or doubt it, as the case may be (Stake and Easley, 1978; Weiss, 1978).

Research on the learning and teaching of science, mathematics, and technological subjects suggests what we should do, but sadly, the current practice in teaching and textbook presentations fails to exploit this knowledge. If the research were applied in texts and instruction, both interest and achievement in science and mathematics would improve substantially, and at a relatively low cost (a subject I shall return to later).

None of the science programs in the past adequately exploited the need of students, particularly young adolescents, for answers to questions that they regard as important, what students call the "so what" of it all—actions, consequences, and values. Late in preadolescence and during the years that follow, youth in every country begin to develop a world view, a set of attitudes—a nexus of beliefs if you will—that ultimately affects their behavior. By observation, through experience, and by talking seriously with anyone who will converse with them, they form their own answers to a recurrent set of twelve questions.

1. What kind of country is this?
2. What values control activities?
3. Where do I fit in?
4. Do they expect me to succeed or fail?
5. How much effort do I need to make?
6. Is success worth the effort?
7. Can I get help?
8. Do I have the energy and endurance?
9. What happens if I do not make the effort?
10. What an I up against? What is the competition?
11. What difference can I make?
12. Do I care? Does anybody care?

Ultimately, we have to decide what science programs, and other subjects as well, ought to contribute to their search for answers.

Under Project Synthesis, a team of twenty-three science educators examined elementary and high school programs to see how well they satisfied four major purposes of science education: (1) science for personal needs; (2) science suitable for dealing with social issues; (3) academic preparation for further study of science; (4) orientation to careers in science and technology. Their aim was "to examine the countenance of science education as it exists at the precollege level and to make basic recommendations regarding future activities in science education" (Kahl and Harms, 1981, p. 5). Although they found no programs that satisfied all four goals in the four large databases and the most commonly used textbooks that they studied, they did find pieces scattered among the programs that could be fit together to fill out portions of the missing components in the science cycle described in Figure 1.

Gaps in the Science Cycle: Why They Exist

Controversies about what the focus in science programs should be arise in part from the failure to keep all four components in perspective. Within the "Ways of Knowing" component, for example, we find the first major difference between what the scientists who led science curriculum reforms that began in the sixties thought was important and what was then, and continued to be, the predominant emphasis in schools. For the most part, teachers and texts concentrate on the question "What do I know?" Emphasis on this question tends to limit the teacher's function to one of conveying information and correcting student recitations. Knowledge is seen as a fixed commodity to be stored up for future use. ("Learn it now. You will need it next year.")

Ordinarily, science programs that operate under this conception of knowledge provide relatively little formal opportunity for students to discuss their own interpretations. The students' primary responsibility is to learn the official story well enough to be able to write it or recite it correctly, regardless of whether they understand it or believe it. Thus the coverage of large amounts of content becomes a prime objective.

Textbook publishers and testing services have responded to this objective overwhelmingly. Science books have grown by accretion, packed with more concepts per page, more pages per book, and more topics to be "covered" than ever before. High school science texts average between seven and ten new concepts, terms, or symbols per page. Typically the 300 to 350 pages assigned during a school year means that students are expected to learn between 2,400 and 3,000 terms and symbols per science course (Ross, 1981; Rowe, 1983). Thus, in a school year of 180 days, and in class periods of approximately fifty-five minutes each, twenty concepts would have to be covered per period, an average of one every two minutes. That there is very little discussion or inquiry should come as no surprise—there is no time for it.

Some sense of the frustration both teachers and students sometimes experience in the face of such pressure is epitomized by the remark of an exasperated ninth-grader as he slammed his very thick Earth Science text down on his desk—"Do you know what this is? It's a damn'd dictionary!"

Standardized tests, or at least teachers' images of them, reinforce the "coverage" pressures that teachers feel, and have as well some undesirable effects on students. Science instruction often amounts to no more than long lists of words to be looked up so that the definitions can be repeated in recitation and on tests. Implicit in this method of teaching is the notion that students are uncritical, essentially bottomless receptacles for information. When it comes to learning science and mathematics, at least, this is an erroneous conception. One has to wonder, parenthetically, what such learning contributes to the search for answers to the students' questions described above.

What students do learn is that someplace there are people who produce the "right" answers. There is always an official response to be recited whether or not one understands it or believes it. Recent research (to be described later in this paper) illustrates how deeply self-defeating this whole approach to science instruction is.

In the sixties, scientists who took part in the reform of science programs wanted more attention given to the other questions in the "Ways of Knowing" component—"Why do I believe it? What is the evidence?" They argued that to understand why science has become so important to the well-being of people and the prosperity of a nation, one has to look at its methods as well as its content. The methods create a capacity for progress by making possible a systematic increase of trustworthy knowledge—that is, knowledge that has been subject to test and verification. Thus they wanted to direct more attention to the methods by which researchers construct reliable knowledge. They wanted students to consider the roots of belief, to examine evidence, to construct explanatory systems of their own that were fundamentally "scientific" in nature. They encouraged students to seek alternative interpretations and to appreciate the provisional nature of explanations. Science, they believed, is a method of constructing reality that depends essentially on *action*. Through action, the correspondence between explanation and phenomena can be checked, and knowledge put to work on our own behalf. But the form of instruction they thought appropriate to achieve their purpose relied heavily on guided inquiry and extensive student discussion—students as active inquirers in search of explanations, as opposed to receivers of information per se—and this created serious problems for many teachers and students alike.

Only engineers had a full grasp of the implications of the "Action" component of the science cycle, but their influence on curriculum was limited. The engineering sciences provide means for joining together the four components of the science cycle because they draw attention to the applications side, the "so what" of it all. Three categories of knowledge are important to the design of solutions to technical problems: (1) how things work (description); (2) why they probably work that way (explanation); (3) what must be done to make desirable outcomes more likely and undesirable effects less likely (forecasting and control). Thus the "Actions," "Consequences," and "Values" components of the science cycle could be realized through the inclusion of an engineering perspective in both mathematics and science (Piel, 1981).

Many of the scientists and mathematicians who took part in the curriculum reforms of the sixties felt that if the basic science in all the items under "Ways of Knowing" was strong, anybody could make applications. That expectation proved to be incorrect. Recent research in physics (McDermott, 1982; Minstrell, 1982) and in mathematics (Clement, 1982; Cohen, 1981) education suggests that strategies for making use of knowledge are complex and must be taught. Even students with good grades in physics and mathematics had great trouble putting their knowledge to use when confronted directly with phenomena, so-called real situations. Moreover, by failing to include sufficient emphasis on implications for action, texts and teachers alike eviscerate one of the most important sources of motivation to learn. Many students see little point to what they are being asked to learn, and they have little enthusiasm for science in the way it is generally conveyed—namely, books that read like dictionaries and classroom sessions that require little interpretation and application from the students (Stake and Easley, 1978).

Trade-offs Between Giving Information and Encouraging Inquiry

Inquiry-oriented instruction brings into contention the purposes of the program and the beliefs of the students about what is true and important. Moreover, it threatens the traditional role of the teachers in controlling the flow of content and determining what the final products of discussion should be.

Typically, teachers ask questions and students answer them. In the inquiry mode, however, more responsibility for producing and evaluating explanations and for asking questions shifts to the students. Attention moves from questions of what we know to how we explain what we know or believe, and in a fully implemented cycle, to discussion of the other three components that relate to application.

The inquiry process incorrectly conceived can lapse into an inquisition as easily as the "tell, text, test" procedure can. During a lesson on earth science, for example, a student's answer to the question why crystals formed in rocks immediately provoked another one from the teacher: "And why is that?" The student gave more information, and again the teacher asked, "And why is that?" After the fourth "why" from the teacher, the student answered in exasperation, "I don't know. God made it that way, and that is that!" Students may learn to say what they are expected to say but believe something else, and it is beliefs that ultimately guide action.

Instead of acting primarily as givers of information and inquisitors, teachers in the inquiry mode will function more as consultants to the student investigators and as managers of materials needed in the laboratory. The students' task will be to construct defensible explanations.

Students come to class with a host of what might be called homegrown conceptions of how the world works, conceptions that are convincing to them but that often turn out to be incorrect in terms of modern science. These misconceptions are quite resistant to change and frequently become barriers to further learning. We now know that simply telling them a different way of thinking fails to unsettle these deep beliefs. There is a growing body of research on specific misconceptions that appear to be learned relatively early in life. Physics ideas have been particularly difficult for people to acquire and use because of prior misconceptions (Clement, 1980; Green, McCloskey, and Caramazza, 1980; McDermott, 1978; Minstrell, 1978; Simon and Simon, 1978; Viennot, 1979). One thing seems clear from this line of research: students will not exchange their naive explanatory systems for scientific ones by being told what to think and say about the two to three thousand concepts and symbols that are now treated in many classrooms and textbooks. The research seems to show that only through exposure to many counter examples, plus a good deal of discussion and argument joined to experimentation, are they likely to transform their perspectives.

Wait-Time and Pacing Factors

Whatever variation of inquiry one chooses, and wherever in the cycle the class is, discussion and argument are essential to intellectual growth in the discipline and to the nurturing of the embryonic roots of scientific wisdom. In fact, however, the prevailing pace of verbal exchange between teachers and students in science classrooms is much too fast for the necessary depth of thinking to take place. The speed of exchange that characterized recitations in the "tell, text, test" pattern proved to be much too rapid for the complex mental processing that the inquiry method requires to function properly.

When teachers ask questions, they generally allow an average of only *one second* for students to begin answers. After a student responds, teachers typically begin a reaction in slightly less than a second (an average of 0.9 seconds). While that rapid pace may be suitable for drill, it spells doom to the kind of discourse needed for more complex thinking. The effect of lengthening the pause following a question and after a response alters the quality of student thinking rather dramatically. ***The changes that result***, only a few of which will be mentioned here, ***highlight the connection between instructional strategies and the kind of thinking that students exhibit.*** For example, the length of their explanations in one study increased on average from twelve to forty words, a 300 percent growth in science-related language production. Inferences were more likely to be linked to evidence without need for teachers to probe for the connections. Students asked more questions, something they rarely do under normal rates of pacing. Logical consistency of their explanations improved, and the number of suitable alternative ideas they expressed increased markedly. Essentially the same effects were found for secondary and elementary schools and in college science classrooms as well (Rowe, 1974, 1980).

Feedback

In the "tell, text, test" pattern, teachers focus on the correctness of student responses, signaled by reactions such as "Good," "O.K.," "Fine," "Right," "No, think again," and these are consistent with the emphasis on the question "What do I know?" Answers, for the most part, are either right or wrong.

Because feedback in inquiry-centered instruction is meant to improve the quality of student explanations, the teacher's task becomes considerably more complex. This kind of instruction requires deeper understanding of the subject and of likely student misconceptions. Feedback is meant to help students assemble explanations that meet such criteria as consistency, congruence with the data, and so on. Challenges to student explanations have three purposes: to resolve differences in explanations; to illustrate why controversy is essential to the progress of science; and to confront values that are implicit in the process of moving around the science cycle. To be effective in the inquiry mode, teachers have to make judgments continuously about the adequacy of student explanations in order to select activities or pose questions that will allow students to discover for themselves when their ideas need to be revised.

As discussed above, wait-times that are too brief have a negative effect on the quality of student reasoning in science. So, also, do many verbal rewards ("Fine," "O.K.," etc.) Contrary to prevalent belief, a high rate of verbal rewarding has a depressive effect on the quality of explanations in science (Rowe, 1974, 1978). If an objective is to build student confidence in their ability to develop explanations and to resolve conflicts between prior conceptions and new explanatory systems, three instructional practices will help:

1. Overt verbal rewards need to be substantially reduced in order to create a relatively risk-free condition for testing ideas.

2. Average wait-times after a teacher asks a question and after a student responds need to be increased from the prevailing one second to three seconds (Rowe, 1974, 1978).

3. Students need many examples and a great deal of time to discuss them if they are to understand concepts well enough to put them to use (Reif, 1980; Robinson, 1981).

In short, the research seems to imply that the current emphasis on rapid presentation of many ideas, with too little time for discussion and too few examples, may produce students who are test-wise and knowledge-poor. The implementation of an inquiry approach, however, poses dilemmas for students as well as teachers at least some of the time. Three anecdotes illustrate how deeply embedded is the idea that there is only one official explanation.

In a chemistry classroom in Palo Alto, California, CHEM Study (one of the inquiry programs developed in the late sixties), students answered questions as briefly as possible, and when the teacher pressed for alternative interpretations, they sat silent. Finally, one of them called out plaintively, "Why don't you just tell us the answer and get it over with? We have to take college entrance exams and need to know the right answers." Then he added, "This inquiry stuff is sometimes kind of interesting, but we haven't got time for it, and besides, it always ends up the same way—what we are supposed to think. We need to know the right answers."

The second illustration of the fact that young adolescents, wherever they may be, form their own answers to the basic questions described earlier comes from a sixth-grade classroom of boys in Kenya, East Africa, where another inquiry-based science program, the "African Primary Science Program," was taught. The sixty boys were organized in working groups of seven or eight each to conduct a small investigation using a few common chemicals. I was the consultant for one of the groups. The boys rather quickly got the idea of controlling variables, in this case, mixtures of chemicals, so that they could identify an unknown powder. Within the group there were differences of opinion about why some of the mixtures bubbled and others changed color. The questions and explanations were theirs, not mine. At the end of an hour, the teacher called the groups together to question them about their findings and explanations. To my surprise, the boys in my group gave answers that were at odds with those on which they had previously reached a consensus. Afterward I asked them why they had done that. In Kenya, where the future of students depends heavily on their test performance, the response made practical sense, "Please understand, madam. We know the way of his knowing must be the way of our knowing, whether we believe it or not."

On a flight to Europe, an eleven-year-old boy from Baltimore watched me analyze some research data with the help of a calculator. At some point he startled me by saying, "How will you know if you are right?" Had he somehow read my own concern? "Where are you going to look it up when you get finished?" he wanted to know. Still begrudging the intrusion, I answered, "There is no place to look it up. I just have to use this answer until there is a reason to change it, maybe when other people think there might be a reason." He was not satisfied. "Someone has to know. If you don't have a book to look up the answers, then you have to ask the teacher." He paused, and then in a tone of sympathy said, "Sometimes they won't tell you. Won't your teacher tell you?" Certainly he had formed his answers to a few of the twelve questions listed earlier.

In science and engineering programs that stress inquiry, the balance between teacher control and student control of what happens in the dialogue is critical. How far off the track should teachers let students wander before redirecting them when they fail to recognize and remedy deficiencies? This question, asked repeatedly by puzzled, time-driven teachers, was echoed in a related form by certain of their students who never lost track of what was really important for their future: "What are they fishing for?"

Logistics

Conditions for operating satisfactory laboratory portions of science programs are much less favorable than they once were. The impact of the changes is greater on an inquiry mode of instruction than on the "tell, text, test" instructional pattern. Inquiry programs rely heavily on activities meant to arouse student curiosity and prompt spontaneous exploration of ideas. Today's classes are larger and more unruly. That means more materials need to be available and managed safely at one time. These conditions increase the risk of injury in an era when teachers are more and more vulnerable to suit.

Everything connected with operating a science program seems to be surrounded with more red tape and restrictions than was once the case—repairs and the purchase of new equipment and other materials involve more paperwork, permission for field trips is more difficult to obtain, safety precautions are more stringent, and so on. One hears remarks like the following from teachers who once ran first-rate inquiry-based programs: "Nobody wants to cooperate on anything anymore. The students don't want to do the work to prepare for field trips and the administrators don't really want you to go. It costs money, and they worry about the things that could happen." "I wait until the summer to take students on trips, because then I just get the ones who are interested. The others have ruined so much for everyone. They couldn't care less." "Because of insurance on the buses, we can't take trips beyond twenty-five miles from the school, and the museums are fifteen miles beyond the limit."

For many science teachers, the groups of bright, enthusiastic students who came to the laboratory after school to work on science projects of their own choosing were the greatest source of satisfaction. Here, inquiry went forward in a very natural way in what amounted to small research communities. With the disappearance of neighborhood schools, and the need to move large groups of students on tight bus schedules, after-school programs, which gave science-motivated students the opportunity to work on projects and to spend time with others interested in science, virtually disappeared. Many schools still maintain an "activities" bus that takes students in the major sports and band programs home at the end of an extended day, but as one teacher remarked angrily, "They don't have room for the science kids. Football and band get priority."

Many teachers are reacting to the deteriorating conditions by retreating to what appears to be the safest and most energy-conserving version of the "tell, text, and test" instructional pattern. Laboratory equipment stands idle, and administrators wonder whether it was a bad investment. This, in turn, makes science with its horrendous vocabulary and what many students consider to be irrelevant content, less attractive. It is treated increasingly as a second-language learning program (Stake and Easley, 1978). Enrollments in nonrequired science course are not rising (Buccino, Evans, and Tressel, 1978), and if we can believe the reports on science performance published by the National Assessment of Educational Progress, students know less science than they did a decade ago (National Assessment of Educational Progress, 1979).

Science and Fate-Control

How well a nation thrives and how rapidly adaptation takes place depend in part on the extent to which a substantial portion of its people understand the connections between possession of scientific and technological knowledge and the power to act effectively on the world. The products of science and engineering indeed produce fundamental shifts in economics and world view, but the methods of science and the values attached to it have the power to shape our sense of purpose and to turn us into architects of our destinies. Too often, however, the way in which science is taught fails to convey any insight into its most powerful features.

As an enterprise, science transcends national borders. Education about science, however, takes place within ideological milieus. Some are hospitable to the culturing of scientific and technological sophistication; others stifle its development. The vigor of science and technology in a country depends in part on which of the two forms of fate-control orientation predominate in the culture. Fate-control refers to a pattern of beliefs about the nature of the world we live in, one's place in it, and the influence one can have on it. It depends in part on how we answer the twelve questions listed earlier.

People with a low sense of fate-control act as if the world were a collage of happenings with few connections between them, as though each event had sprung uninvited into their lives. The world for them is unpredictable, like a game of chance. As a rule, their knowledge and understanding of science tend to be rather primitive, if not totally absent. This lack of knowledge gives license to their belief that nothing is worth any sustained planning since the world is in the grip of powerful forces and people beyond influence.

People with a high fate-control outlook function as if they believed that events have roots that evolve by processes they can discover and thereby possibly influence. People of high fate-control orientation are more keenly attuned to cause-and-effect and to the structure of relationships between events and ideas. Because they believe that the future grows out of what one does in the present, they are more disposed to participate in long-term plans and

TABLE 1
Characteristics of Low-Fate and High-Fate Control Views

LOW-FATE	HIGH-FATE
Chance—can't influence odds	Can influence odds
No use to try—you can't make a difference	Try things—learn from experience
Little prior evaluation of possible consequences of action	Evaluate outcomes and use information
Now-oriented—here and now rewards	Future-oriented—delayed risks OK
Low task persistence	High task persistence
School achievement lower	School achievement higher
Passive	Active
Weak problem-solving strategies	Aggressive problem-solving strategies
Susceptible to influence	Relatively resistant to influence
"How I do things makes no difference in how things turn out."	"How I do things makes a difference in what results I get."
Goal-setting is irrelevant	Goal-setting is irrelevant
Displaces responsibility outward	May be excessively self-blaming

projects. Table 1 contrasts high and low fate-control perspectives on the world; there may, of course, be many gradations between them.

The world views encapsulated in the terminology of fate-control extend over two major domains of knowledge. On the one hand there are social phenomena. To the extent that people understand something of their nature and think of themselves as able to influence others, their ability to function effectively in complex social and economic institutions is increased (See, for example, Lefcourt, 1974). On the other hand, there are phenomena, such as are encountered in the natural sciences and the explanatory systems, upon which the progress of a scientifically and technologically sophisticated world depends. The two domains intersect at the point where science is brought to bear in the service of health, technology, conservation, and other areas. As Figure 1 suggests, the natural and social sciences provide a substrate out of which young people could compound answers to their questions that would help to cultivate a world view that is more highly fate-control oriented. And if the study of ethics is included in their education, the probability that they would develop a high fate-control perspective is greatly increased (Christianson, 1982).

To illustrate how reasoning differs among children with low fate-control orientations as compared to high, consider the following anecdote from early research on this topic (Rowe, 1975). In two elementary school classrooms in two different schools, students were divided into groups of four. Each group had a small aquarium with six or seven guppies in it to care for over a period of several weeks. One Monday in November, they discovered, when they came to school, that many of the guppies had died over the weekend. In one class, members of several groups immediately began to argue over whose fish were dead and who owned those that were left. The response in the other class was quite different. Students mostly puzzled over why the fish had died and what they could do to save those that were still alive. (Over the weekend, the temperature outside had dropped, and there was no heat in the schools. The temperature change was apparently too much for the fish.)

Even among scientists, those with a higher fate-control orientation appear to be more productive (Hardy, 1974), since they are apparently able to tolerate ambiguity for a longer period while they examine a wider array of alternative hypotheses. Inquiry programs have a similar purpose: namely, to contrast what one knows with possible alternative interpretations, and then to take considered action (see Figure 1).

Special Problems of Elementary Science

Perhaps one of our most serious concerns should be the virtual disappearance of science in grades one through six (Rowe, 1980, Buccino, et al, 1982). Children begin absorbing and creating explanations about things "scientific" when they are very young, and although some of these homegrown theories are sound, many are not. As the research repeatedly shows, misconceptions can be firmly embedded rather early in life and can block future learning. Furthermore, the research suggests that concepts and explanations must be experienced on many occasions over time and in different contexts. It was partly for these reasons that the elementary science programs developed in the sixties put such emphasis on direct experience with phenomena, on how the processes for producing knowledge are related to what we believe in science. It seems clear that exposure to science throughout elementary school would help establish more appropriate "scientific explanatory systems" and therefore lessen the need to do so much unlearning in later years. Science programs that include many simple investigations not only help develop better explanatory systems, but also have a beneficial effect on language development as well (Bredderman, 1982; Wellman, 1981).

There appear to be five reasons why science is disappearing in the early grades. First, despite its substantial contribution to language development generally, science is nevertheless a low-priority subject, drowned in the back-to-basics waves that inundated most education programs in the last decade. Second, this image of science is reinforced by the fact of its usual omission in district-wide testing programs. Third, it has few advocates; if science is left out of the school week, nobody complains. Fourth, it takes more time to prepare the equipment and materials for a science lesson than it does, for example, a lesson in the social sciences, to say nothing about where the material and equipment can be left safely until the time they are needed. Yet science, if taught in the inquiry mode, requires only simple equipment and materials. Fifth, of all the major subjects in the elementary curriculum, science produces the most anxiety for teachers. School administrators say their teachers do not know enough science; teachers say the problem is twofold—a lack of time to prepare, and finding the time to put science into an already crowded school program.

An Agenda for the Eighties

In his introduction to the Carnegie Institution of Washington *Year Book '62*, Caryl Haskins says,

> *Greatness in a nation, like personal greatness, is a measure not only of character, not only of excellence, but also of enduring significance both in ideals and the shape and goals of effort. In any society, but perhaps especially in our own, such greatness must necessarily be valued in coin of our own design and minting, whose very significance, moreover, we must ourselves determine. (1963, p. 3)*

It is doubtful whether a democracy can afford to leave large sections of its population ignorant of science and untutored in technology. In the long run, such a decision could undermine the political and economic viability of the nation. Knowledge of science and use of scientifically based technologies may complicate our lives, but lack of it saps our will. Thus the first of a dozen recommendations for future action would be to

1. Extend science for general education to more students over longer period of time.

2. Extend support for science programs on television (e.g.,"3–2–1 Contact," a science program for ten- to twelve-year-olds produced by the Children's Television Network).

3. Examine existing books and curricula in terms of the science cycle in Figure 1, and modify or add to those so that all components of the cycle are included.

4. Examine the social studies and humanities portions of the curriculum to determine what these subjects can contribute to the implementation of a full cycle. In a cogent article, "Understanding Science as a Cultural Phenomenon," D. Christianson remarked, "The human element refers to all the unexamined forces energizing and shaping science from within and from without. It is private ambitions, corporate motives, and public goals; it is lofty purposes and public expectations; it is group loyalty and professional allegiances (Christianson, 1982).

5. Put existing research to work in the service of curriculum development and instruction, to close the too-great gap between current practice and current knowledge. In recent years, the problems specific to learning science have begun to be researched, and although the work is far from finished, there are some very important findings for the teaching of science, particularly the teaching of those physical science concepts that have been a source of failure for so many people. Incorporation of current research into both instruction and textbooks would produce gains in science understanding.

6. Increase the motivation to study science by making the engineering sciences and the applications side of the science cycle more visible in the curriculum, and include these practical aspects of science more frequently in classroom discussions.

7. Involve scientists and engineers from both industry and universities, as well as science educators, in curriculum planning and in the conduct of programs for inservice science teachers.

8. Employ computers in the instructional process, not just for drill and practice, but to give students access to whole arenas of knowledge that would otherwise be missed. (Computers are patient and forgiving of mistakes, but most important, they help the student to develop a point of view essential to a high fate-control orientation: namely, they make the process of feedback far more effective than it can be under what are now standard conditions in a classroom. When programs fail to run as expected, students can control them by debugging [fixing them] based on immediate feedback.)

9. Keep in mind the twelve questions adolescents ask repeatedly as they develop their world views. Provide opportunity for discussion and use resource materials that will help them develop better explanatory systems.

10. Reorganize textbooks in light of research on *what* and *how much* really ought to be covered in a course.

11 Develop accountability procedures that reflect those aspects of the science cycle which are finally incorporated into program.

12. Provide summer science programs for inservice teachers that allow them to learn about research currently under way in the sciences and in science education, and that provide them with occasions to participate in some way.

Science for a Democracy

When an American science education delegation was visiting China a few years ago, one of the members conducted a brief inquiry session for teachers so that they could catch the "flavor" of the method. The Chinese teachers did the small experiment and argued over explanations vigorously. A lot of good science emerged in the discussion, and it was difficult to draw their attention back to the reason for the demonstration. Their interest had been caught. Finally, one of them said, "But why do you do things this way? Why don't you just tell them what they are to think. That is more efficient."

Each one of us must answer that question. A saying of Chuan Tsu, an ancient Chinese philosopher, provides one answer: "The pheasant in the marshes has to take ten steps in order to get one beakful of food; one hundred steps for one drink of water. Yet it doesn't want to be kept in a cage. Though it would be fed like a king, it would not be happy."

In a democracy, we have to teach ourselves how to live successfully outside the cage—how to be free. Science has a place in that teaching. *How* we do it matters. *Why* we choose to do it in particular ways also matters. As Gwen Frostic, an artist and poet from Michigan, tells us in her book *Beyond Time,*

We must create a great change
in human direction—
an understanding
of the interdependency
by which the universe evolves
Know
—that knowing—
is the underlying foundation
for the life we must develop....
We cannot leave it to the scientists—
nor any form of government—
each individual
must fuse a philosophy
with a plan of action.

We must begin the process of developing scientific wisdom suitable for our time. It can be argued, with good justification, that as the programs of science education decay, so will the potential to shape the future to our own benefit, to maintain some control of our own destiny.

Refer. nces

Bredd an, T. (1982). The effects of activity-based science elementary schools. In M. B. Rowe (Ed.), *Education for the eighties: Science* (pp. 63–75). Washington, DC: National Education Association.

Buccino, A., Evans, P., & Tressel, C. (Eds.) (1978). *Science and engineering education: Data and information.* Washington, DC: U.S. Government Printing Office.

Christianson, D. (1982). Understanding science as a cultural phenomenon—mission of the 80's. In M. B. Rowe (Ed.), *Education for the eighties: Science* (pp. 17–24). Washington, DC: National Education Association.

Clement, J. (1982, August). *Analogical reasoning patterns in expert problem solving.* Paper presented at the Fourth Annual Cognitive Science Society Meeting, Ann Arbor, MI.

Cohen, S. A. (1981). Effects of teaching sixth-grade students to modify format variables of math word problems. *Reading Research Quarterly 16*(2), 175–200.

Green, B., McCloskey, M., & Caramazza, A. (1980). Curvilinear motion in the absence of external forces: Naive beliefs about the motion of objects. *Science 2*(10), 1139–41

Hardy, K. R. (1974, August). Social origins of American scientists and scholars. *Science.* 497–506.

Kahl, S. & Harms, N. C. (1981). Project Synthesis summary and implications. In N. C. Harms & R. Yager (Eds.), *What research says to the science teacher. Vol. 3.* Washington, DC: National Science Teachers Association.

Lefcourt, H. M. (1974). *Locus of control.* Hillsdale, NJ: Lawrence Erlbaum Associates.

McDermott, L. C. (1978). Problems. In R. Siegler (Ed.), *Childern's thinking: What develops?* Hillsdale, NJ: Lawrence Erlbaum Associates.

McDermott, L. C. (1982). Problems in understanding physics (kinematics) among beginning college students—with implications for high school courses. In M. B. Rowe (Ed.), *Education for the eighties: Science* (pp. 106–128). Washington, DC: National Education Association.

Minstrell, J. (1982). Conceptual development research in the natural setting of a secondary school classroom. In M. B. Rowe (Ed.), *Education for the eighties: Science* (pp. 129–143). Washington, DC: National Education Association.

National Assessment of Educational Progress. (1979). *Three national assessments of science: Changes in achievement, 1969–77, 1978.* Washington, DC: National Center for Educational Statistics.

Piel, J. E. (1981). Interaction of science, technology, and society in secondary schools. In N. C. Harms, & R. E. Yager (Eds.), *What Research Says to the Science Teacher. Vol. 3.* (pp. 94–112). Washington, DC: National Science Teachers Association.

Reif, F. (1980). Theoretical and educational concerns with problem solving and education: Bridging the gap with human cognitive engineering. In D. T. Tuna & F. Reif (Eds.), *Problem solving and education: Issues in teaching and research* (Chapter 4). Hillsdale, NJ: Lawrence Erlbaum Associates.

Robinson, J. (1981). Research studies of science instruction in middle and junior high schools. In P. Hurd et al. (Eds.), *The status of middle and junior high school science. Vol. 2: Technical report.* (pp. 213–276). Boulder, CO: Center for Research and Evaluation, Biological Sciences Curriculum Study.

Ross, N. M (1981). Analysis of middle and junior high school science programs. In P. Hurd et al., (Eds), *The status of middle and junior high school science. Vol. 2: Technical report.* (pp. 145–212). Boulder, CO: Center for Educational Research and Evaluation, Biological Sciences Curriculum Study.

Rowe, M. B. (1975). Ecology of an urban ghetto. *Learning Magazine.*

Rowe, M. B. (1980). Elementary science: A vanishing species. *Science and Children, 18*(1), 19–21.

Rowe, M. B. (1980, June). *Science and fate control: Implications for the teaching of primary level science.* Paper presented at the Conference of Primary Science, UNESCO, Paris, France.

Rowe, M. B. (1974). Relation of wait-time and rewards to the development of language, logic, and fate control. Part one: Wait-time. *Journal of Research Science Education, 11*(2), 81–94; Part two: Rewards. *Journal of Research Science Education, 11*(4), 291–308.

Rowe, M. B. (1983, November). Getting chemistry off the killer course list—Rigor without mortis. *Journal of Chemical Education, 60*(11).

Rowe, M. B. (1980). Pausing principles and their effects on reasoning in science. *New Directions for Community Colleges, 31,* 27–34.

Rowe, M. B. (1974). Science that kids can live by. *Learning Magazine, 2*(9), 16–21.

Rowe, M. B. (1978). *Teaching science as continuous inquiry.* New York: McGraw-Hill.

Stake, R. E., & Easley, J. A., Jr. (1978). *Case studies in science education.* Urbana, IL: Center for Instruction Research and Curriculum Evaluation, University of Illinois.

Viennot, L. (1979). Spontaneous reasoning in elementary dynamics. *European Journal of Science Education, 1*(2), 205–21.

Weiss, I. R. (1978). *Report of the 1977 national survey of science, mathematics, and social studies education.* Washington, DC: U.S. Government Printing Office.

Wellman, R. T. (1981). Science: A basic for language and reading development. In M. B. Rowe (Ed.), *What research says to the science teacher. Vol. 1.* (pp. 1–12.) Washington, DC: National Science Teachers Association.

Over the course of her career, Mary Budd Rowe has been a teacher, lecturer, and consultant in science at all grade levels. Her research on "wait time" in teaching has been called one of the most important discoveries in education in the past two decades. Dr. Rowe's study of another topic—the role of early exposure to activity-based science programs in the development of fate control—has also been highly publicized. She was president of NSTA in 1987–8, and is a professor of science education at the University of Florida

What Makes the Science Program and Science Supervision Viable?

How to Support Your Science Program: An Introduction

5

EMMA WALTON
ANCHORAGE SCHOOL DISTRICT

Science education merits the collective best of all factions of the community. Science educators must be vocal, visible, untiring advocates for their disciplines, prepared to go the proverbial extra mile. Although this essay represents neither the final word nor the only way to support science education in schools, the approach outlined here has worked in successful science programs across the nation.

Financial Support

Of the many kinds of support necessary to keep a science program viable, money is one of the most critical. Without adequate funding it is nearly impossible to obtain the materials and equipment needed to teach science effectively. Science supervisors in many districts must be vocal and organized to secure equitable financial support for science programs, thus enabling students to not only read about science and technology, but interact with it.

Support from Administration and Boards of Education

No science education program can succeed without the support of the local school board and administration. As these groups provide funding, establish policy, and formulate a school district's philosophy, they must constantly be informed of the science program's needs. This can be a difficult task. School administrations manage many issues, and science is seldom given high priority, especially if the administrators or board members themselves had difficulty studying it in the past. The science supervisor must work to improve the image of science for these groups. This will help them share a sense of ownership and responsibility for the program, keep them up to date on the latest research and directions of the field, and encourage them to seek advice on how to solve problems in the delivery of science education. Both bodies must be kept informed of all science education happenings.

There should never be surprises. There are many ways to involve administrators and boards. Some are the following:

- Show enthusiasm about science and share students' interest in the subject
- Invite observers to classrooms when a teacher is working well with students
- Provide concise information to the right people on what the latest research says about the need for quality science education
- Provide opportunities for students to be involved in science fairs and olympiads
- Honor students and involve administrators in award assemblies and similar events
- Write news releases for the media highlighting students' and teachers' achievements. Provide action photos for display
- Recognize publicly those science teachers who really make lessons come alive and who are naturals in promoting science
- Arrange press interviews for teachers to highlight programs and boost teachers' images
- Conduct work sessions in which teachers can share effective teaching methods and focus on their needs

Community Support

Many of the procedures listed above will establish ties with the community, an essential relationship that takes time and effort to cultivate. When science supervisors fulfill their responsibility to constantly inform the public about the status of science education, their programs are likely to be supported. Parents enjoy seeing their children recognized. Small gestures like "Science Student of the Week" certificates can let parents know that the faculty cares about the students. These ritual celebrations may seem difficult or trivial, but they work to publicize programs.

Other suggestions for involving the community include:

- Appointing citizens to curriculum committees
- Inviting science professionals to judge science fairs
- Serving on the boards of outside organizations to forge links between them and the schools
- Working with parent-teacher organizations to help raise funds for science activities
- Involving the arts community in the selection of logos, posters, and designs
- Inviting volunteers to chaperon field trips
- Requesting help in gathering materials for science experiments and activities

Science supervisors must also work for cooperation and support from local industry and businesses. To take advantage of this support, however, science leaders need a clear definition of their program goals. A well-defined program makes it possible to evaluate community resources and use those which are appropriate to the goals of the curriculum.

There may be times when science supervisors need to redirect efforts of the community. For example, if a group who wants to work with the school offers materials counter to the science program's philosophy, the supervisor will have to help the group understand the direction that science education is going. Skillful persuasion can make the difference between an advocate and an adversary.

Science educators have to be willing to teach the public along with the students and to involve the community in its schools.

Support from Teachers

Science curricula imposed from the top do not always succeed. If teachers are not consulted about curriculum changes, the chances of the science program's success diminish considerably. Involving teachers in the design of the science program lets them make sure their concerns are met, lets them "own" the curriculum, and makes implementation easier. Teachers know how things work in the classroom. There are several avenues to involve the teaching staff:

- Contract with teachers to write full curricula or specific activities. Textbook series or programs can be purchased; however, to localize the curriculum, have teachers construct supplemental units to make the instruction relevant to the area. Curriculum writing activities can build a cadre of experts: If a teacher has a problem with a specific part of the unit, she or he has a primary source of information at hand.

- Promote involvement through committee work. Making decisions about curriculum, tests, and projects should not be one person's responsibility. Discussions about what science education should be can improve science offerings.
- Encourage membership in science education organizations to foster professional growth and communication among teachers. Such organizations support their members and are able to solve problems beyond the control of individual teachers. Membership in a larger group can build a sense of professional pride and identity.
- Work with local colleges and universities to highlight the research they are doing, as well as to participate in joint projects and grant proposals.
- Recruit postsecondary faculty as advisors and committee members.

The Role of the Science Supervisor

A science supervisor has a complex, multifaceted job, full of day-to-day tasks and the challenges of working with many groups.

To be effective agents of change, supervisors should

- Develop wise time-management habits
- Develop a support system of science educators who are both visionaries and workers
- Make time to read and keep up to date in science and science education
- Become actively involved in professional organizations, especially the National Science Supervisors Association and the National Science Teachers Association
- Exchange ideas with colleagues from across the country
- Work with supervisors from other disciplines to foster cooperation and interdisciplinary approaches to teaching and learning

There are too many variables to guarantee the complete success of any science program, but knowing the tasks and putting in time and effort can certainly help to make science meaningful for students. Central administration, the school board, teachers, colleges and universities, and the community must join to deliver an exemplary science education program. This kind of support doesn't just happen; it is a result of persistence, creativity, and plenty of hard work.

References

Aaron, Merik R. (1988, February-March). Time management. *Science Scope, 11*(5), pp. 38–39.

Drucker, Peter F. (1980). *Managing in turbulent times.* New York: Harper and Row.

Harbeck, Mary (Ed). (1976). *The second sourcebook for science supervisors.* Washington, DC: National Science Teachers Association.

Holdzkom, David, & Lutz, Pamela (Eds). (1984). *Research within reach: Science education.* Washington, DC: National Science Teachers Association.

Peterson-Dillon Betty, Brandt, Ronald S.,& Olson, Nancy (Eds). (1981). *Staff development/organization development.* Washington, DC: Association for Supervision and Curriculum Development.

Zumwalt, Karen K.(Ed).(1986). *Improving teaching.* (Yearbook.) Alexandria, VA: Association for Supervision and Curriculum Development.

Emma Walton, a science education coordinator, has been on the cutting edge of developing and implementing hands-on/minds-on science programs. She is the author of numerous papers and articles on science education and has made presentations locally, nationally, and internationally. She is the 1988–89 president of the National Science Supervisors Association.

What Keeps the Science Program Viable? A California Model

6

GARY A. NAKAGIRI
SAN MATEO COUNTY OFFICE OF EDUCATION

Teaching science is difficult, especially if students are to learn the processes of scientific investigation through hands-on activities and experiments. Difficult, but not impossible: many thriving science programs are the direct result of the hard work and long hours of dedicated teachers. What makes these teachers willing to put forth their best, while at other schools, teachers compete to see who can be the first to leave after the last bell rings?

The answer is simple: if teachers are proud of their program and see the tangible results, the rewards of their efforts, then they will do any amount of work necessary to maintain that program.

For the science supervisor or administrator, the question then becomes how do you help teachers maintain a good program? What support, resources, leadership, and intangibles are required to keep a good program going? Let's first examine some of the key elements of a good science program.

Some Key Features of a Good Science Program

A good program includes the following features:

- *A staff that works together.* Whether the staff is large or small, programs function best when everyone involved contributes their unique skills and expertise; synergism is a tremendous multiplicative force.

At a Southern California junior high school, the science staff met every day during lunch to plan future science lessons. Several members would assist each other in gathering and organizing the materials for the laboratory activities; others would be preparing or revising the homework, written work, and tests. Since only two of the five classrooms were equipped with lab facilities, scheduling classes into the labs at appropriate times was tricky but possible with a lot of cooperation. The teachers worked together in a *truly supportive, professional fashion.*

• *Opportunities for teachers to gain new ideas.* To prevent stagnation, even good teachers need to attend workshops and conferences to assess their own programs and gain new ideas. In their search for exemplary science programs, review teams consistently find that the teachers involved rarely feel that their programs, however exemplary, have attained their full potential; the teachers always believe something more needs to be changed or added.

The science staff, often as a whole, regularly attended various science conferences and summer institutes to pick up new ideas to enhance their program. Obviously, they did not feel their program was the "best," nor did they shun new ideas.

• *Administrative support and encouragement.* If a science program is to have an adequate budget, scheduling, resources, facilities, and favorable publicity, it must have proper administrative support. Most importantly, administrators who are proud of their science programs will be more willing to provide that support and the means for their maintenance.

The staff has now dispersed; the department chairperson left in disgust, while several other teachers have transferred to other schools. The main reason: lack of administrative support. The principal, for whatever reasons, had scheduled different lunch periods for the science staff, cut their budget, and restricted the number of classrooms available for shifting classes between the labs and regular rooms.

• *Tangible benefits to students.* The success of any program can only be measured by the benefits students derive from it. Students in good science programs demonstrate a more positive attitude toward science, perform scientific tasks more competently, and have a better conceptual understanding of science.

Many other features could be added to this list. NSTA has made a valuable contribution to science education by publishing monographs describing exemplary science programs. Concerned educators should focus on the key features of those exemplary programs and adapt them to fit their situations.

The question still remains: How can such programs be kept alive? Theodore Manolakes (1975) describes several basic roles common to most curriculum supervisors. Specific examples of these general functions are included in the following section, together with some suggestions.

The Supervisor's Roles

The supervisor as seed planter and program extender

According to Manolakes, supervisors "might not see their ideas initially accepted or implemented, but this is part of the seeding process. Time, interaction, and an evolving situation often lead to eventual acceptance and implementation" (pp. 53–54). Such "seeds" might take the following forms:

• New, creative forms of staff development. For example, San Francisco secondary science teachers had a unique opportunity to participate in a workshop presenting a curriculum supplement developed by New York City schools. The supplement correlated written materials with all 12 segments of David Attenborough's *The Living Planet* series on public television. Two factors made the workshop unusual: (1) the joint collaborative efforts of the San Francisco Zoo and California Academy of Science (teachers spent a half-day at each facility); and (2) the classroom sets of the supplements, plus teachers' guides, colorful posters, and student handouts teachers received at the end of the workshop. Teachers were obviously excited and well-prepared to integrate portions of the series into appropriate sections of their course.

• Old forms of curriculum/staff development with new twists. Most districts will allocate funds for textbook selection/adoption workshops and meetings. Those opportunities should be enhanced by building time into the schedule to provide staff development and networking/sharing possibilities.

• Cooperative plans with site/district administrators. Administrators' interest in science-related curriculum and staff development rises prior to, during, and immediately after a district science textbook adoption. This is the time to plant the innovative seeds that will make those curriculum and staff development plans more successful, and ensure sustained support.

• New student programs with a subtle staff development component. A select number of high school students are participating in a science enrichment program on weekends at the Marin Headlands area just north of the Golden Gate Bridge. While the primary beneficiaries are students, several San Francisco high school teachers serve as instructors, teaming with the Headlands Institute staff. The emphasis is on field biology, and the program provides an excellent opportunity for these teachers to practice teaching methodologies that are usually difficult to implement within an urban environment. These teachers also have an opportunity to interact with, plan with, and learn from other science educators.

• Innovative incentives. Earthwatch, a program in which teachers, businesspeople, and other interested individuals participate in scientific research trips throughout the world, is now available to San Francisco teachers. Scholarships that cover all or nearly all of the total costs have been awarded to four teachers each summer for the past several years. The selection criteria includes the willingness of the applicants to share what they have learned with their students and colleagues. For many science teachers, this is their first opportunity to participate in actual scientific research.

The supervisor as technical helper

Much of the time supervisors spend with teachers and administrators is devoted to serving as the "expert" in science-related curriculum and staff development matters. Teachers may request suggestions for curriculum ideas for specific topics, such as marine biology. Administrators may need assistance in setting up appropriate curriculum development sessions for their teachers to revise their current scope and sequence. When outside expertise is required, the following suggested sources may be valuable.

• Working relationships with nearby colleges or universities. For example, a summer institute program for middle school science teachers was cosponsored by the San Francisco school district and San Francisco State University. The district science consultant provided the technical expertise, while the participating college professor complemented the program with his clinical supervision experience during the practice teaching phase.

• Federal and/or state resources. The National Diffusion Network, a Department of Education program, provides information and technical assistance on validated exemplary curriculum and staff development programs. Several science programs from the Network have been adapted for use by San Francisco teachers.

The California State Department of Education has developed several publications to provide teachers and administrators with K–12 science education curriculum guidelines. One notable document is the State Science Addendum, a supplement to the State Framework specifying the science content and process skills that should be taught to students in K–12. It is used as the basis for state textbook selection criteria and item selection for the statewide testing program.

The supervisor as a personal support person

Perhaps the most important role the supervisor can play from an individual teacher's point of view is that of an interested and supportive person, a professional who meets the teacher's real need for an ally with whom to talk, share problems, and receive positive encouragement. Such a role might include the following activities:

• Development of professional relationships with site administrators. Administrators often need support and encouragement, too. An unintentional result may be the administrator's greater understanding of and increased support for the school's science programs.

• Staff development programs that support science teachers, especially those without a strong science background. Nearly half the present San Francisco middle school science teachers do *not* have a major or minor in a science area. Consequently, a program was developed to identify school teams of these teachers and provide both technical and personal support. In addition to relevant workshops, the district science consultant observed classes and provided the personal support essential to teachers unsure of their content area.

• Special support for new teachers. The research is clear: Nearly 50 percent of all new teachers leave the profession after three years or less. With the current and continuing shortage of qualified science teachers, all possible efforts should be mustered to assist and facilitate the difficult transformation from neophyte to competent teacher. The San Francisco school district is now considering a "beginning teacher" program: the key elements will include technical and personal assistance with classroom management and discipline, as well as effective teaching strategies, such as mastery teaching and cooperative learning.

• Links with the local teacher education programs. If you have the opportunity to serve as instructor or consultant to a teacher preparation science methods course, take it! Working with enthusiastic, idealistic, prospective teachers is fulfilling, and establishing important personal and professional relationships with them will pay off when they have their first teaching assignments.

The supervisor as expediter

No matter how effective the program, teachers need someone to help them, at times, with such basic requests as ordering textbooks or supplies. The solution to such a small but critical concern may be simply providing the latest catalogs or prices. More significant efforts might involve circumventing district or school policies that impede the implementation of certain programs. Supervisors should be skilled in assisting teachers in negotiating some flexibility with their administrators without disregarding the intent of those policies. Some examples:

• Assisting teachers with field trip plans. District policy may prohibit mandatory field trips that impose student fees to help cover costs. At one San Francisco high school, a tidepool field trip was made a science club-sponsored (rather than course-sponsored) activity, and was considered optional, with appropriate alternative assignments: as a result, over 90 percent of the biology students were able to go by paying a small "voluntary" field trip fee. It has since become a course tradition.

• Assisting teachers in obtaining their release from classroom assignments to either visit other schools or participate in staff/curriculum development efforts. A regional NSTA convention was held in San Francisco some years ago. To provide substitutes so that some of teachers could attend during school hours, the San Francisco district curriculum coordinator was persuaded by the science consultant that letting teachers attend was a cost-effective means of providing staff training. The consultant subsequently had to canvass all 28 junior and senior high schools, prepare a detailed board resolution, listing all of the teachers that would be released; appear at an evening board meeting to support the resolution; and work with the personnel office to ensure that an adequate number of substitute teachers for each of the schools was available. In many cases, substitutes covered for two teachers so that each could attend for a half-day. All the work was worthwhile because the teachers came back excited and recharged with new ideas.

The supervisor as informant and communication stimulator

Facilitating the flow of relevant information between teachers is important; encouraging networking among teachers with similar concerns or interests leads to cooperative efforts and higher quality results. Such schoolwide networking tasks would include:

- Establishing and maintaining regular means of communication among teachers of similar interests. Monthly high school department head meetings are common in many districts. Representatives from the 16 middle schools in San Francisco also meet on a regular basis, and elementary science resource/mentor teachers have met occasionally. Elementary principals of schools involved in a special elementary science implementation program have met and currently network with each other.

- Encouraging and publicizing teachers with creative ideas that may be applicable to other schools. Several mentor teachers have offered workshops on their newly-developed curriculum ideas. By knowing the needs of teachers in similar teaching situations at different schools, the supervisor can make personal contacts prior to the workshops to encourage these teachers to attend relevant sessions.

- Expanding existing programs by encouraging more teachers with congruent interests to participate. The San Francisco Middle School Science Fair began with 4 teachers at 2 different schools. It has now expanded to 6 schools and 12 teachers who have the opportunity to share ideas on how to effectively conduct school fairs, assist students with projects, and establish judging criteria and procedures.

- Keeping administrators informed. Certain administrators tend to "push" science more: keeping them well-informed of upcoming workshops, conferences, and other items of interest pays off because they will encourage their staff to participate.

Larry Cuban (1969), a former director of staff development for the Washington, DC, public schools, argues against the existence of curriculum supervisors. He bluntly states: "The supervisors are powerless to cope with the concerns of teachers. What teachers need—smaller classes, time to plan and think, opportunities to analyze with others what happens in a classroom, freedom to experiment, and support for that experimentation—supervisors cannot provide" (p. 215). His skepticism is a constant challenge to all of us who believe that science supervisors *can* make a difference with teachers in the classroom.

References

Cuban, L. (1969). The powerlessness of irrelevancy. In Leeper, R. (Ed.) *Supervision: Emerging profession* (pp. 214–217). Washington, DC: Association for Supervision and Curriculum Development.

Manolakes, T. (1975). The advisory system and supervision. In Sergiovanni, T. (Ed.), *Professional supervision for professional teachers* (pp. 51–64). Washington, DC: Association for Supervision and Curriculum Development.

Gary Nakagiri is currently the curriculum coordinator for science and mathematics with the San Mateo County Office of Education. He spent 16 years as a secondary science teacher and district science consultant for the San Francisco Unified School District. He is the 1987–89 NSTA Director of Supervision.

The Science Supervisor's Role at the Local Level: A Tennessee Model

7

JACK RHOTON
EAST TENNESSEE STATE UNIVERSITY

Many variables influence the role of the science supervisor: district size, grade span served, philosophy and approaches to learning, available resources, and the plethora of wide-ranging topic areas in science. Even the job title—science supervisor—is synonymous with several science categories. Depending on the school district involved, the science supervisor may be science consultant, director of science, department head, science coordinator, or be called science teacher with other work responsibilities.

Regardless of the title conferred on the individual leading the science program, his or her primary goal is to bring about improvement in the total science program with the involvement of teachers, administrators, community, and all professional channels. The avenues by which this is accomplished vary with the degree to which emphasis is placed on curriculum and instruction, staff development, pesonnel, staff management, school-community relations, school equipment, outside resources, and other areas. This in turn is affected by the supervisor's working relationship and amount of communication with the staff, and his or her creativity, initiative, and leadership style.

The intent of this article is to present the role of the supervisor, from the author's point of view, in maintaining a viable science program at the local level. Having been a science supervisor in a local school district for 12 years, the author has discovered that positive, viable, and long-lasting changes are usually precipitated by the leadership qualities the supervisor brings to the program. For good or bad, the science program will eventually reflect the personality and qualities of its leadership. Major responsibilities rest on the supervisor's shoulders to make the program the best it can be. The efforts of the supervisor will affect the program's philosophy and goals, curriculum development, instructional techniques, budgets, and human relations.

Group Participation in Successful Science Supervision

The science supervisor must address the issues and problems affecting the science program. What direction is the science program to take? What goals are to be accomplished? What topic areas are going to be included? What approaches and methodologies are going to be used? To answer these and other questions, the participation of several groups—teachers, science supervisors, administrators, parents—is essential. Good science supervision demands that a statement of philosophy and goals be developed and put in writing. The supervisor must involve as many groups as possible that are influenced, either directly or indirectly, by the philosophy and goal statements. The philosophy is a beacon that provides direction to the science program from the inception of curriculum design to actual implementation and evaluation. The supervisor's leadership ability is crucial in assisting the staff to translate the philosophy and goals into actual student learning experiences. Curriculum implementation must mirror the philosophy and goals established.

A science program appropriate for one school district is not necessarily appropriate for another school district. The needs of the community and the makeup of the student body will influence the science curriculum. Also, a good science program will match its curriculum to the resources available at the local level, including nature centers, industrial sites, universities and colleges, rivers and lakes, and human resources.

Effective planning and an emphasis on curriculum development and revision is essential for good science supervision. The primary aim of science education is developing scientific literacy. Three parts comprise this goal: Students need to accumulate a body of scientific knowledge, understand the impact of science and technology on their daily lives, and recognize the importance of the role of science process in learning. The science program must include learning opportunities for all of these factors.

There is a need to focus on not only the specific skills and concepts incoming students should know, but also on what students are expected to know when they move on to the next grade level. This is required in other subject areas, and it is important for it to be done in science as well. Too often, science, especially at the elementary school level, is relegated to the last few minutes in the school day—if it is covered at all. In many schools, science is not considered part of the curriculum until sixth or seventh grade.

In a viable science program, it is essential that science skills and concepts be planned, organized, and implemented in such a way that it becomes a sequential science program, K–12. A steady progression of learned skills becomes cumulative and allows for previous knowledge to be used to acquire further knowledge. The unplanned science program leads to the isolated learning of pieces of science that have little connection with each other or continuity for the student.

It is important that concepts/skills and terminal objectives be fashioned at each grade level. Developing concept/skill cards for each level is one way to keep track of student understanding and mastery of science concepts/skills. This method allows the teacher to mark on the card if the concept/skill is being introduced, developed, reinforced, or extended. Also, it permits the teacher to track students' level of knowledge of the concepts presented. The main advantage of this system of record keeping is that it provides the next grade level teacher with a general format of what concepts and skills the student has been exposed to and his or her general understanding of those concepts. Additionally, this information allows the teacher to focus on the student's strengths and weaknesses. Using a numbering system, the concept or skill can be keyed to previously identified laboratory activities that allow the teacher to match the concepts and skills to a process-oriented science program.

The science supervisor has the responsibility of working with his or her staff in establishing and maintaining a balance between the product and process of science. It is not uncommon for science programs to emphasize teaching the facts, laws, principles, and theories of science, with little or no inclusion of science processes. Science is more than learning a predetermined body of knowledge. It is a process of letting students act out their natural curiosity by experimenting and drawing conclusions. Acting on the innate curiosity of students, the teacher can provide experiences that allow students opportunities to explore and explain their natural environment, thereby leading them to devise and test their own explanations of things encountered during the exploration.

Science is not static: it is both a product and process and must be presented as such. Science must be recognized as a verb: it is the act of doing and investigating. This type of science allows for real-world problems and issues to be addressed. To accomplish this end, the science program must use all the science process skills: observing, classifying, measuring, communicating, predicting, inferring, hypothesizing, and experimenting. The role of the science supervisor in planning for a balance between the product and process of science is not always an easy one. However, the person leading the program must be more than a facilitator; he or she must become a partner with the teacher in establishing the program's philosophy and goals, the curriculum, and an evaluation program to insure that the overall curriculum is consistent with the identified needs of the student.

Effective Staff Development

Another critical factor in nurturing the science program lies in staff development. The supervisor is responsible for providing appropriate experiences for the staff that will lead to more effective K–12 instruction. Working with teachers, the supervisor must identify staff development needs and arrange for a comprehensive staff development program aligned to the existing curriculum, its goals, objectives, and long-range plans. Providing the opportunity for teachers to meet both formally and informally to study, review current research, evaluate, and recommend solutions to science curriculum problems is one key to nurturing a healthy science program.

An effective staff development program is continuous and built into the system. This arrangement prevents haphazard planning of workshops and inservice programs that may or may not be geared to the improvement of instruction. The supervision process should be sensitive to not only teachers as a group, but to individual teachers as well. This sensitivity should manifest itself in encouraging teachers to attend professional meetings, make presentations, and take additional course work. A carefully planned staff development program is essential for maintaining quality and assuring real and lasting changes in the science program.

Authority and Credibility

The science supervisor, if effective, is able to speak with some authority and must have credibility as a spokesperson for the arena of science. The supervisor must have knowledge of different areas of science to be able to communicate effectively with the staff. Without this foundation, the ability to serve as an effective leader is hampered. Local commitment for science education from the board of education, for example, gives credence to the supervisor's role. The supervisor's credibility is further enhanced through commitments and demonstrated leadership in professional organizations. Attending meetings and presenting sessions that are pertinent to identifying or solving issues and problems facing the profession keeps the supervisor aware of new developments in science education. The supervisor's participation in activities such as joint planning groups, university-based seminars, task forces, and other group projects should be a high priority, as it helps keep staff members abreast of new developments that can affect the way they perform their jobs.

Funding Sources

The individual leading the science program must be not only supportive of a strong budget for maintaining adequate supplies, equipment, and staff development, but also aggressive in searching for outside funding sources, such as the National Science Foundation and other governmental and private granting agencies. Discovering the priorities and focuses of these agencies and the areas targeted for improvement becomes important for the supervisor as proposals are prepared and submitted for possible funding. Establishing links that lead to cooperative and collaborative partnerships with business and industry, colleges and universities, and cultural and professional institutions and societies can all be used to strengthen the total science program. The supervisor can make these resources work for the program. (See "Grant Seeking: Searching For the Pot of Gold" in this volume.)

Science Beyond the Classroom

Good science leadership must make available opportunities for extracurricular activities: science fairs, science clubs, after-school and Saturday events, summer science programs, and science bowls. These opportunities allow students to reach beyond the regular classroom, which stimulates further interest in the field of science. Extracurricular events serve as additional methods of making science relevant and meaningful, while simultaneously providing an avenue for students to explore career opportunities. The positive feeling engendered by these events is extremely valuable in facilitating communication between parents, students, and the school.

Meeting Students' Needs

One of the hallmarks of an exemplary science program is its ability to meet the needs of all students, whether they are average, gifted, or have learning difficulties. Science as content, product, and attitude is interwoven into an exemplary program. Inherent in this approach is a wide variety of choices made available for students to meet their individual needs. Listed below are some examples of science programs initiated by teachers, administrators, and the author that allow students to explore science in creative ways.

Environmental Education: An Experimental Problem-Focused Approach for High School Students

High school students exhibit vivid and genuine concern for environmental issues. The judicious teacher attempting to channel this curiosity into truly comprehensive problem-focused learning experiences may be inhibited when confronted with the organizational constraints of the typical school day. To overcome such restraints, a community problem-focused summer school program was developed for secondary students.

The new course, "Field and Human Ecology," (FHE) is offered as an elective. The class meets for six hours a day, five days a week, for four weeks. Successful completion of the summer course allows the student a full science credit that can be used to fulfill graduation requirements.

The overriding purpose of this course is to provide realistic opportunities for high school students to become actively involved in determining sources, investigating causes, and suggesting alternatives to community environmental problems.

The initial segment of the course is devoted to developing and refining the skills and techniques to be used by students in gathering and interpreting environmental data. Next, students form study teams of two and three and select specific community problems for further research. Examples of student research projects selected and conducted include microwatershed studies, the detection and measurement of atmospheric pollutants, a survey of excessive sources of noise, and an analysis of the role of local, state, and federal agencies in providing and maintaining environmental quality.

A [illegible] of the course time is spent outside the classroom. With the high school serving primarily as home base, nearby industrial sites, rivers, lakes, and areas of urban blight, among others, serve as instructional support facilities throughout the course. Visits to these facilities are designed to provide students with firsthand opportunities to make observations and collect data relevant to local environmental problems.

To provide a balanced view of the trade-offs and alternatives which must be considered when confronting many environmental problems, community resource personnel, including local industrial and business representatives, are invited into the classroom for discussion with students. Further clarifications of opposing views on specific problems are obtained by student-arranged interviews with environmentalists, industrial leaders, and city officials.

Students participating in the course have three major responsibilities: (1) an individual responsibility; (2) a small group study team responsibility; and (3) a responsibility to the group as a whole.

The individual student assumes the following responsibilities: (1) to read pertinent books and articles, assigned and unassigned; (2) to work within the framework of the small group research team; and (3) to communicate study conclusions to the total group.

To obtain closure and aid in evaluating overall course impact, study teams submit a final project report. Each team uses the following format to conduct and report its community study: (1) brief history of the problem under investigation; (2) record of the data collected and the methods utilized; (3) conclusions supported by findings; and (4) specific recommendations as to how the local problem can be solved. Copies of these final reports are forwarded to the appropriate city officials, local industries, and the Environmental Protection Agency.

The author believes one note of caution is in order for science educators considering such an approach. A single course in no way constitutes a comprehensive environmental education program. Rather, a course can serve as a foundation for the development of a total program or a method of broadening the scope of the existing program.

Science Partners Program

The primary aim of the Science Partners Program is to encourage exploration of science in everyday life and to increase parent interaction with the student. To accomplish this goal, student and parent(s) work together to complete 15 science-related activities at home. An information packet providing an overview of the program, agreement forms for both students and parents to sign, instructions for recording activities as they are completed, and a suggested list of ideas is sent to parents at the beginning of the year.

If the student and parent(s) are interested in participating, they are asked to sign the Science Partners Agreement form and have their child return it to the teacher. The student agreement form simply states that he/she agrees to work with his/her parent(s) in completing at least 15 science-related activities. It is further agreed that he/she will keep a record of each activity and provide a written record to his/her teacher when 15 are completed. The written record includes the name of activity, a brief description of what was done, amount of time spent on project, and completion date. Similarly, the parent agrees to work with the child in completing all activities and agrees to provide any required materials and/or transportation. To help both the parent(s) and student identify ideas, a list of 40 suggested activities is provided. Parents have the options of selecting from this list or creating their own activities. The suggestions range from taking a "field trip" through the kitchen and looking for examples of various simple machines to walking through the neighborhood and making a list of examples of physical and chemical weathering and discussing what could be done to prevent or slow weathering.

As each activity is completed, the student has the responsibility of sharing his or her experience with the class. If the program is completed, the students are presented with a certificate and small trophy at the end of the school year. The enthusiasm generated by participating parents adds excitement not only to the elementary curriculum, but also contributes to a positive atmosphere in the total school program.

Summer Science Challenge Program for Elementary and Middle School Students

Providing opportunities for students to participate in summer school is an avenue that can be used to enhance and enrich any existing science program, especially for elementary and middle school students. The author has worked with teachers for several years in implementing a summer science enrichment program for students in grades 3–8. Hundreds of students who have demonstrated an acute interest in their regular science classes participate in the program each summer. Even though the participants are selected according to their interest, they are not all academically gifted. On the contrary, many are average and even below-average ability level students. They have one thing in common: a strong interest in science.

Teachers make available information concerning the Summer Science Challenge Program (SSCP) early in the school year. Based on interest and parent approval, all are given an opportunity to participate. The primary purpose of the program is to foster insight and creativity for each participant in several areas of science. Specific objectives of the program help participants become better science students by.

- creating a greater interest in science
- learning skills that can be carried over into the regular classroom
- creating familiarity with high school science facilities
- becoming aware of high school science offerings
- working and sharing with students from other schools
- allowing students to consider career choices in the sciences
- becoming active investigators
- learning laboratory safety skills

Students in the SSCP attend classes for five days, seven hours per day. Several weeks of SSCP are scheduled throughout the summer, depending on the number of students enrolled. The high school science laboratory facilities serve as home base. Since SSCP is geared to a "hands-on" approach to science, students pay a fee which covers the cost of instruction, equipment, and consumable materials. Local middle and high school science teachers are employed as instructors for the program.

The curriculum is arranged in a way that allows participants to investigate many and varied topics through laboratory experiments and teacher demonstrations. Students design and conduct their own experiments in order to answer a question or solve a problem. They do not know for certain what the outcome of the experiment will be. Along with designing and carrying out the experiment, they learn how to identify controls and a variable that can be manipulated. Further investigations allow students to record the results and draw tentative conclusions based on their work. The program covers chemistry, biology, and physics. Examples of lessons include electricity and magnetism, gases and air, and anatomy using dissections of fetal pigs, cows' hearts, and sharks. Topics are selected based on student interest from past programs and availability of materials and equipment.

"Sciencing" Conferences for Students

Opportunities for "sciencing" that go beyond the regular classroom are provided through the vehicle of science conferences. These conferences are planned and implemented periodically throughout the school year, usually on Saturdays. The conference is housed in the local high school science facility. The school auditorium accomodates the general meetings, while the small group sessions are held in the classrooms. Scheduling the conference on Saturday has two primary advantages: it allows all interested students an equal opportunity to participate, and it eliminates the school district's responsibility of having to transport participants to and from the conference site.

Students at all levels are invited to participate; however, the programs are generally geared to the middle and high school levels.

The primary purpose of each conference is to give participants an opportunity to have contact with the latest developments in science, medicine, and engineering. A major speaker such as an astronaut or nationally known scientist is invited to speak on a specific topic. During the same conference, experts from across the country share and exchange ideas on the leading edge of science. Conferences have been held on such topics as innovative technology, biomedical engineering, computer chips, futuristics, genetic engineering, and robotics.

Conference speakers are scheduled several months in advance, and many are willing to participate without an honorarium. If the science budget does not allow for bringing conference participants in from greater distances, usually local or regional experts in many fields of science are happy to share their time and talents with students.

A viable science program is one that meets the needs of the local community. Maintaining a viable science program requires the efforts, collaboration, and consultation of teachers, supervisors, administrators, and community leaders. Instructional improvements must be the major goal of both teachers and the science supervisor. The supervisor works with teachers toward creating an environment that is conducive to nurturing and encouraging self-confidence, diversity, and tolerance in the staff.

To accomplish the program goals, new ideas should be encouraged and supported so that each teacher may feel a sense of importance and pride as the group's personality is established. Teachers who feel a sense of ownership will go that extra mile to demonstrate their purpose, commitment, and dedication to make the program the best it can possibly be. This includes working with students after school hours, teaching summer school, holding weekend science competitions, utilizing community resources, spending time on extended field trips, assisting with curriculum development, and encouraging special programs for their students. The science supervisor should be aware of the fact that the effectiveness of any staff depends, to a large degree, on the effectiveness of its leader. In the final analysis, it is the science supervisor who influences the personal commitment, collective effort, and cooperation of the total group.

References

Felsen, M. E., & Ritz, W. C. (1979). Science supervision in New York state: An examination of supervisor-science relationships. *School Science and Mathematics Journal, 74* (6), 465–472

Harbeck, B. (Ed.) (1976). *Second Sourcebook for Science Supervisors*, Washington, DC: National Science Teachers Association.

Harris, B. M. (1963). *Supervisory behavior in education.* Englewood Cliffs, NJ: Prentice-Hall, Inc.

Rhoton, J. (1984, March). *A study of science education in Tennessee as perceived by teachers and principals.* Unpublished doctoral dissertation, The University of Tennessee.

Voss, B. A. (1981). A summary of research in science education. *Science Education, 67,* 289–419.

Jack Rhoton, science educator, has experience in science supervising and teaching in the public school system. As past president of the Science Association of Tennessee and currently the Association's newsletter editor, he has directed numerous externally funded projects and authored publications in several professional journals. He has taught science education at East Tennessee State University since 1987.

Centers for Science Education: A North Carolina Model

8

PAUL B. HOUNSHELL
UNIVERSITY OF NORTH CAROLINA

JOSEPHINE [illegible]ETT
EAST CAROLINA UNIVERSITY

Each year, some 150,000 teachers graduate from over 1300 colleges and universities in the United States, many with advanced degrees in education. Yet, even with this concentration of effort, there is a serious shortage of science and mathematics teachers in the nation's public and private schools. As a result, science and math are being taught by inadequately prepared or certified teachers. Surveys are showing that as time goes on many of the better prepared teachers will leave the classroom for other professions. We need to overcome these problems and develop solutions by consolidating the efforts of higher education, the science supervisor, the elementary and secondary school community, and the private sector.

One strategy which has withstood critical analyses by an advisory group representing school systems, the university, and the local community is the North Carolina Mathematics and Science Education Center Network, a program dedicated to strengthening the ongoing professional development of science and mathematics teachers. One of ten Centers in is located on the University of North Carolina-Chapel Hill campus, and has its own staff and funding. This Center provides university support to increase the supply of qualified science teachers and improve opportunities in the field of science education.

The Center was developed with the following goals:

- To increase the quality and availability of mathematics and science teachers in North Carolina's public schools
- To strengthen science and mathematics instruction in middle and high school programs
- To sponsor basic research and development in mathematics and science education
- To increase the effective use of educational technologies in all schools

Science supervisors have played a key role in the Center's development from the very beginning. Even before advisory boards were officially created, area supervisors were providing valuable advice and soliciting opinions from their teachers. Later, as advisory board members, science supervisors were instrumental in shaping the role the science education center would play.

The Center for Science Education

There are many ways in which a university center for science education can improve local science teaching. Such a center can tap the best resources of a university and make them available to the public schools: It can coordinate resources from all sectors on campus, ranging from the Colleges of Arts and Sciences, to Colleges of Education, Engineering, and Medicine. Working with a center, science supervisors and other school administrators can examine and seek approaches that bridge the gaps between the needs of classroom teachers and the overall school system needs. Centers, then, are also uniquely able to communicate these needs to higher education and, working together, all three sectors can produce solutions.

Science centers can take the lead in improving science education by developing a variety of support options—academic course work, institutes, seminars, symposia, colloquia, and workshops on science content and teaching—for teachers and students. The following are examples of North Carolina's approach to consolidating higher education's resources for the improvement of science education in the schools.

Programs

Centers, with joint planning from science supervisors, can focus on programs to update teachers' backgrounds in and understanding of science content and methodologies. Programs can be a sequence of courses that lead to certification and advanced degrees. In fact, the need for programs developed specifically for middle school teachers served as the rationale for the creation of the Center concept in North Carolina.

Five years ago, as a result of requests from area supervisors and their teaching staff, the Center started a middle school mathematics and science program for teachers. The supervisors and teachers who made the requests helped design the program and assisted with end-of-course evaluations.

The UNC–CH Center first looked at the middle school mathematics and science teacher education programs already in progress, and began building from the point of teachers' needs. The strategy of this middle school program was to improve the quality of science and mathematics instruction by providing teachers with a sequence of academic courses; the cost of tuition was shared by the Center and the school systems involved. The first course combined math and science emphases for one group of carefully selected middle school teachers. During the semester, half the time was devoted to science and science methodology and the other half to math and math methodology. The objective was to provide an opportunity for participating teachers to receive instruction in both mathematics and science, leading to examination and discussion of how the subject matter of both areas was interrelated. At the end of the semester, however, evaluations revealed that teachers preferred one subject at a time to allow in-depth study of each area. These evaluations led to the development of two separate ongoing courses, one in mathematics and one in science.

Institutes

The various Centers of the North Carolina Network and the Department of Public Instruction cooperatively sponsor a series of summer institutes for teachers in all areas of science throughout the state. Mathematics and science teachers of grades six through nine enroll during the summer, usually for a five- to six-week session. Each institute has a university faculty member and a master teacher from the public school system as instructors. Each teacher receives a stipend for attending, and earns course credit applicable to certification or renewal certification.

Science supervisors are instrumental here, too, in making the program a success. They are involved at the state level in funding proposals, and at the local level in course offerings and participant recruitment and selection.

As the school system contact, they offer their expertise, experience, and knowledge of the needs of both their system's teachers and students.

Courses

Summer programs alone cannot meet all of the development needs of mathematics and science teachers. Therefore, the Center offers specific course topics designed to strengthen the content background and teaching skills of teachers. Course topics are selected by science supervisors and teachers themselves and focus on areas such as botany, physics, and geometry. Courses organized through the Center at UNC–CH were taught by two university professors, one from the targeted content area and one from the School of Education.

Workshops

Another area of professional development often requested by teachers deals with the presentation of special topics and issues. Workshops and seminars presenting programs on Advanced Placement Physics, Advanced Placement Chemistry, Advanced Placement Biology, and Advanced Placement Calculus; Acid Rain and Air Pollutants Symposium, Science Laboratory Safety for Grades 7-12, and Project Equals: Encouraging Women and Minorities in Mathematics and Science, were all organized by the UNC–CH Center for area teachers. All were well-attended because they responded to a need articulated by the science supervisors and their teachers. School systems paid for substitutes and, in many cases, for travel to attend the programs.

Curriculum Improvement

Centers can be the catalyst for curriculum improvement, and curriculum development projects provide supervisors and teachers with opportunities for leadership. One such project is the Marines Sciences Curriculum development project jointly sponsored by the UNC–CH Center, the UNC Department of Marine Sciences, North Carolina Sea Grant, and regional schools. Teachers, science supervisors, and university faculty are preparing marine sciences materials that can be integrated into any of the sciences taught at the secondary level—biology, physics, earth science, and chemistry. In addition, they are correlated to specific performance objectives of the North Carolina State Department of Public Instruction Course of Study. The project includes curriculum development, field testing, revision, inservice, dissemination, and evaluation. Four teachers and four science supervisors compose the team developing these materials.

Support Services for Teachers

In addition to direct services for professional development, centers for science education can provide a variety of support and resource functions for teachers. Several programs were developed through the UNC–CH Center to provide support for area teachers. These included a local biology teacher support group, a "hotline" resource directory, and a materials information center.

A biology teacher support group was formed by teachers in surrounding schools and spearheaded by a university faculty member. The teachers wanted to create opportunities to meet with peers and discuss topics of concern. The group decided to meet once a month at participating member high school sites, rotating the location of its meeting to the different high schools in the area. At the first meeting of each year the group arranges the schedule and meeting sites and works with the university science education faculty member to locate speakers and various discussion materials. Word of the success of the group spread to science teachers in other areas, who have now formed similar groups in both chemistry and physics.

The Science and Mathematics Education "Hotline" is a publication which lists UNC–CH specialists in the areas of mathematics, science, and health sciences. A listing of faculty members, topic of expertise, and contact telephone numbers is included in the publication. These "telephone campus consultants" allows teachers to contact experts directly with any questions in the various areas of expertise. This resource was coordinated by the Center, compiled by Center personnel, and mailed to all local elementary, middle school, and secondary schools.

Another support service is the materials information center, where teachers at all levels, including university faculty, can request information on a wide variety of topics. This type of center service can provide information on topics such as tests in science, software, trade book information, textbook information, and many others.

Support Services for Students

Centers can encourage all kinds of student participation in science. One major means is through student science competitions. The opportunity for students to conduct and present their research, meet with university and private sector scientists, visit research facilities, and compete with their peers is enormously valuable. The UNC–CH Center sponsors student activities such as the Junior Science and Humanities Symposium, the statewide algebra contest, and various science fairs. These are all highly regarded by students, teachers, and parents.

Tutorial programs are another approach to encourage student participation in science. Centers can support graduate assistants working as student tutors in order to complement, enrich, and support the instruction of regular classroom teachers. Students, through tutorial assistance, will be afforded a greater opportunity to explore science concepts and skills, and examine practical applications to real life situations involved in the study of science.

Research

Centers serve another valuable function by sponsoring and conducting research in teaching and learning in science and mathematics. The UNC–CH Center is currently involved in research projects on the preparation of middle school science teachers, on teacher characteristics, and on science teacher burnout. For each of these projects, a local science supervisor is co-director.

Funding Support

Centers, with their associations with universities, are in a strategic position to seek external funding to support their efforts. Competitive grants and corporate gifts are their two major external funding sources. A recent trend in funding proposal guidelines is the notion of partnership, which encourages business, industry, government, and community agencies to join the university in combined efforts towards improve science instruction in the schools.

The existing middle school programs served as the UNC–CH Center's basis for seeking and obtaining corporate support for tuition and stipends. The Center, local and regional school personnel, and private corporations jointly developed strategies to support middle school mathematics and science teachers. The UNC Center received two gifts from the corporate sector to support this program. One gift was a computer laboratory from the IBM Corporation, the other was a teacher fellowship program from the Carolina Biological Supply Company. Both companies contribute to existing programs and stand as examples of how the corporate sector and the university can strengthen science education.

For the Carolina Biological Program, 20 mathematics and 20 science teachers have been given the opportunity to participate in a three-year sequential program designed to update and strengthen content background and teaching skills. To guide development of this program, the Center convened a special advisory panel of science supervisors from local and state levels, representatives of the university, and industry representatives. This group makes policy decisions, and their recommendations are the key to the program's success.

The Center received additional support through Title II funding, which provided area teachers with a middle school botany program and a middle school integrated science program. The botany program provided teachers with 36 hours of classroom, laboratory, and field activity to update both their knowledge of local flora and their teaching skills. The Integrated Science Program brought area teachers to campus for a year-long series of two-day workshops on topics such as astronomy and chemistry for the middle school curriculum. Once again, science supervisors were involved in all phases of program development, from content emphasis to meeting planning.

These examples of the partnership ventures could serve as models for the search for financial support from the private sector and funding agencies.

Centers can be valuable partners in the effort to improve the education in science and mathematics in American schools. The examples cited are only a few ways in which centers for higher education can join with supervisors to strengthen the teaching of science. There are hundreds of others. In every one of these examples, the science supervisors are advisors and participants, the link with school systems, and an advisory group for center growth and development. With cooperative ventures between school systems, universities, colleges, and the private sector, improvements and reform in science education continues.

References

Madrazo, G., & Motz, L. (1982, December). Science supervisors—an endangered species? *Science Teacher, 49*(9), 42.

Ritz, W. C., & Felsen, M. F. (1976). A profile of science supervision in New York State. *Science Education, 60*(3), 339–351.

Shrigley, R. L. (1980). Science supervisor characteristics that influence their credibility with elementary school teachers. *Journal of Research in Science Teaching, 17*(2), 161–166.

Sousa, D. (1984). Recent trends in secondary science education in New Jersey. *Journal of Research in Science Teaching, 21*(3), 269–276.

Voss, B. E. (1983). A summary of research in science education—1981. *Science Education, 67*(3), 289–419.

Wan, J., & Corbett, W. (1978). The liaison teacher extends the science director's effectiveness. *Science and Children, 16*(2), 38.

Paul B. Hounshell is a Professor at the University of North Carolina at Chapel Hill. He has taught grades 7–12, and was the supervisor of science for 3 years in Winston–Salem, NC, and for 3 years in Charlotte, NC. At UNC–CH he has directed NSF academic year, summer, and inservice institutes, and now teaches science education courses at both the undergraduate and graduate levels. He has served on the NSTA board of directors and has been on numerous NSTA committees. He is the author of a number of books and journal articles.

Josephine Duckett teaches science education at East Carolina University, NC. She was formally a science resource teacher with the Charlotte-Mecklenburg Schools, NC; education coordinator fc Discovery Place and Charlotte Nature Museum; assistant director of UNC-Charlotte's Math and Science Education Center; and associate director of UNC-CH Center for Math and Science Education. She has conducted numerous student service camps and workshops for teachers, supervisors, and curriculum specialists. Her major research interest is in examining student conceptions and structures of knowledge in science. She is the author of articles in Science and Children *and* Science Activities.

Managing Change in the Science Program 9

ROBERT K. JAMES
TEXAS A AND M UNIVERSITY

SHIRLEY M. HORD
SOUTHWEST EDUCATION DEVELOPMENT LABORATORY

HAROLD PRATT
JEFFERSON COUNTY SCHOOL DISTRICT

The Superintendent of Schools, Anycity, USA, recently expressed frustration to his science supervisor. He recounted how just two years ago the supervisor had convinced him of the need to change elementary science programs. The new program included much more emphasis on direct, concrete learning experiences for children. A teachers' committee had recommended the adoption of a new hands-on approach. After some discussion the superintendent had been able to convince the Board of Education that it was necessary to spend money on a new text, the materials and equipment needed, and the hiring of a consultant to conduct training for teachers during the August inservice.

Now, two years after the adoption of the new approach, in a meeting of elementary school principals, it has been reported to the superintendent that boxes of equipment remain unopened and in storage. Classroom observations of science teaching reveal a didactic approach, and some teachers have not yet begun to use the new materials.

"Why?" the superintendent asks.

In this we see the quandary which confronts many science supervisors. Science programs may be wisely chosen or developed locally; initial teacher training may be provided. The adoption process may even include a strategy for establishing "ownership" by some or all local teachers. Yet all of these actions cannot guarantee that newly adopted programs will be used in classrooms.

Anycity School's experience in science is little different from most schools. After more than a quarter century of significant national investment in science education, little change has been observed. What have we learned from these past 25–30 years? It appears that promoting change through the development of programs and materials that work well for students is not enough to ensure that teachers will use them. Obviously, we do need updated materials from time to time, but merely providing more new materials will not revolutionize science teaching.

We believe that the problem lies not in the lack of materials, but in the lack of staff development, support, and assistance for teachers as they attempt to implement the new materials and change their science teaching methods. In short, the problem lies in the change process itself. The good news is that we know a great deal more now about how teachers implement change than we did one or two decades ago, and we know how to bring the process to its successful conclusion. This knowledge has come from studying the efforts of schools implementing new programs, including programs on inquiry-oriented science. This chapter will focus on what we have learned about strategies for implementing new curriculum practices successfully, and will discuss the facilitating role of the science supervisor, how change affects teachers and their science teaching behaviors, and a case study of a successful implementation effort.

Understanding the Facilitator's Involvement

Because of the disappointing lack of robust implementation of new curricula, staff at the Research and Development Center for Teacher Education (R&DCTE) at the University of Texas at Austin studied teacher and school change (1973). These studies were designed to produce new understanding about how teachers change their classroom practices, and what is required to support their efforts. Such studies have provided valuable insights for science facilitators into how to bring about successful change, and the importance of their role in this process.

Who Facilitates Curriculum Implementation?

The initial studies of the R&DCTE involved teachers engaged in implementing new curricular programs. Subsequently, in the Principal-Teacher Interaction Study (PTI), the role of the elementary school principal was explored to identify principals' relationships to teachers and their contributions to the change effort (Hall, Rutherford, Hord, and Huling-Austin, 1984; Hord and Hall, 1987).

Because much attention in research journals and the popular press had been devoted to the importance of the principal in the change process, the R&DCTE studies were planned to focus on what principals did that made them such an important factor. Other researchers have confirmed the importance of the principal's involvement with teachers in science programs (Archer, 1970; Carlson, 1965). To the researchers' surprise, an unexpected discovery was made during initial field work in elementary schools: principals were not the only significant persons relating to and supporting teacher change. Additional school and central office-based staff and administrators were participating with teachers and principals in important ways. These persons were labeled the Second Change Facilitator (Second CF) (Hord, Stiegelbauer, and Hall, 1984); by virtue of their position, power, and influence, the principals were assumed to be the First CF. The term "facilitator" was chosen very thoughtfully to apply to these helping persons: regardless of who they were or where they came from, their role was one of assistance.

Who are these facilitators who assist teachers in implementing new science and other teaching practices in their classrooms? The PTI study looked into this question in three schools in each of three school districts: Three schools and their teachers were implementing an objectives-based mathematics curriculum, three schools worked with a hands-on inquiry-approach science program, and three elementary schools were adopting a writing competency curriculum. In all these schools, the principals, to varying degrees, served as the First Change Facilitators. As stated earlier, however, there also were Second CFs. In all the elementary schools in the PTI study, and subsequent studies of successful change in high schools, it was revealed that Second CFs were active in those settings as well (Hall and Hord, 1985; Hord and Diaz-Ortiz, 1987; Hord and Murphy, 1985; Hord and Rutherford, 1985). Sometimes the Second CF was the assistant principal; other school-based Second CFs included resource teachers, department chairpersons, or grade-level chairpersons. At the district level, Second CFs, who were very involved with particular schools, were science supervisors/curriculum coordinators, subject specialists, or specifically titled science facilitators. Interestingly, whether the Second CF was school-based or central-office-based appeared to be related to the principal's "change facilitating style" (Hall, et al., 1984).

In addition, Third CFs were identified in some of the schools. Typically, these were teachers whose roles were less formalized but nonetheless real to their peers and to the successful implementation of hands-on science. How did all these facilitators relate and work, and what does this study say to the science supervisor? It reiterates what is commonly believed about the importance of the school principal in effective implementation. It also says that other persons within the school or district structure are important in affecting implementation. Finally, it suggests a cooperative effort involving the supervisor and a building implementation that includes the principal.

What Do Facilitators/ Supervisors Do?

The Principal-Teacher Interaction Study incorporated a methodology for documenting the actions (interventions) that were made for curriculum implementation (Hall and Hord, 1987; Hord and Hall, 1982; Hord, Hall, and Zigarmi, 1980). These studies documented four distinct categories of interventions as especially significant for supporting change: the supply of materials and logistical support; adequate inservice/training; monitoring; and consultation and reinforcement. Arons (1983) cited the lack of adequate logistical support and the lack of properly guided teacher inservice as "primary causes of the apparent failure of the new science curricula." The PTI study confirmed that monitoring teachers' progress and providing one-to-one consultation and problem solving were needed for curriculum change (Hord and Huling-Austin, 1986) These four types of interventions are briefly discussed below.

Supplying Materials and Other Arrangements

Inadequate logistical support can torpedo science teaching before it begins; on the other hand, appropriate and sufficient materials and equipment provide strong encouragement for science instruction.

Teacher A: *I was heartsick! I opened the* Mystery Materials *kit to plan for teaching it the following week, and the powders in the packets were in a mess! "Who did this!", I was wailing, when into the building waltzed the district science supervisor, smiling, if you please. "What's up, do you need some help?" Can you believe what she did—got it all straightened out in half an hour. It would have taken me days!*

Quality inquiry-oriented science experiences for students demand materials, equipment, space, and the careful organization and management of these resources. An initial one-time supply is not sufficient. Science supervisors will need to provide resources on an ongoing basis. This may call for "creative" acquisition and manipulation of resources. For instance, one elementary science supervisor engaged volunteer parents to organize and assemble kits of materials for the teachers. Another high school supervisor "broadly reinterpreted" the guidelines for spending available funds in order to provide equipment to science teachers so they could make progress in implementation. Even when fiscal support is abundant, however, the logistics will be labor-intensive.

Training

There is a popular belief in the "Three Step Fable" which suggests: (1) give teachers the box of science equipment and printed materials, (2) provide a half-day orientation, and (3) bid them "God speed and good luck" (the implementation benediction). Though this strategy has been unsuccessful in the past, it continues to be broadly used—to the detriment of quality science teaching.

Teacher B: *This inservice session is a blast, and this workshop leader is making it all make* *sense. I just built a circuit board, and now I can really understand how batteries, wires, and bulbs can work together. I'm beginning to understand now how the kids will go about designing and conducting their investigations, and the insights they will gain from their "like a scientist" experiences. This program is dynamite—for me and them. Wait until next month when we get to come back to learn about velocity and falling objects. I'm impressing myself with what I'm learning.*

Training and teacher development, like supplying resources, must be continuous if teachers are to develop the competence and confidence to use an inquiry-based approach to teach science. Training should be designed to take into account teachers' individual needs and concerns (more about this in the next section); it should be tailored for developing teachers' understanding and skills and attend to adult learning factors. We can learn much about successful teacher inservice training, but we already know much about inservice training that we are not using.

Monitoring

All supervisors know that providing the materials and resources for teaching science is vital. Training, though often done poorly and inappropriately, has also been recognized as essential. What has not been given sufficient attention is the monitoring of teachers' work as they begin to change their practices.

Teacher C: *My principal came by my classroom yesterday after school. "How's it going with the Earth Science unit?" she asked. "What kind of assistance do you need?" I was, well, to put it mildly, stunned and delighted. I gave her an earful, essentially admitting that I was really having trouble. You'll never guess what happened next—she left a note for me today saying that help was on the way. She must think science is as important as the basics!*

All of the PTI study schools were successfully implementing new science and other curricula, and the teachers were monitored. Rutherford (1985) asserts that effective principals are characterized by several behaviors, one of which is monitoring teachers' classroom work. Hall and Hord (1986) support the principal's role as an active facilitator and monitor but maintain that the important factor for implementation is that *the process is monitored* regardless of whether the principal does it single-handedly, or has it done by some other facilitator/supervisor. Assessing specifically how progress is being made is vital to successful science program implementation.

Consultation and Reinforcement

Some science supervisors have called this activity "comfort and caring" (Pratt, Melle, Metzdorf, and Loucks, 1980); Louis (1986) terms it "at-the-elbow assistance." Whatever the label, it means interacting with teachers individually to help them solve their science teaching implementation problems.

Teacher D: *I've been so slow to catch on to how to incorporate science process into my science classes and provide the students with these hands-on experiences. My science "coach" videotaped my class and we analyzed it yesterday. Having someone to study it with me and provide insights into what was happening as the lesson developed was really helpful. And he gave me a nice compliment for part of what I was doing!*

Consulting with teachers individually to provide relevant and timely assistance contributes to the development of their competence and confidence in using inquiry science programs. Few teachers can become successful with new programs on their own. Clearly, this type of facilitation, including coaching, consultation, and technical assistance, is another integral part of the support teachers must have to implement new programs.

In summary, we have spotlighted the essential role of science supervisors and other science facilitators, and have suggested that these facilitators may come to this role from various positions within the school and school district.

Managing Implementation Based on Teacher Concerns

Those who have the responsibility to facilitate change in science will surely agree that the four kinds of interventions—supplying materials, adequate training, thorough monitoring, and consultation and reinforcement—provide a rational and systematic approach. Further, they are likely to concede that little attention has been focused on monitoring or providing consultation and reinforcement.

Intervention strategies must be shaped by the unique needs of teachers and local districts. In the past, the supervisors/ facilitators have had to rely on their intuition or on vague implementation concepts such as "ownership" to direct the implementation process. Science supervisors need to design interventions based on local implementation data. The tools that can be used to monitor implementation and teachers' concerns are presented in this section and the next.

Implementation has been the focus of a theoretical construct known as the Concerns-Based Adoption Model (CBAM). The CBAM grew out of the work of Fuller (1969), who studied the concerns of preservice teachers as they moved into student teaching. She observed that their concerns evolved through a sequence beginning with concerns about themselves (self concerns), moving on to task concerns, and culminating in impact concerns. Subsequent work by Hall, Wallace, and Dossett (1973) suggested that this sequence was developmental, and that it was useful in understanding the concerns of teachers as they encountered the introduction and use of innovations in their classrooms.

The R&DCTE staff used Fuller's three-step model to develop the seven Stages of Concern (SoC) about the innovation (See Figure 1).

To provide a quantitative measure of SoC, the 35-item Stages of Concern Questionnaire (SoCQ) was developed. The SoCQ consists of seven subscales with five items each. The data are converted to percentile scores by subscale, and each is plotted as a graph similar to those

Figure 1. Stages of Concern About the Innovation

0 **AWARENESS:** Little concern about or involvement with the innovation is indicated.

1 **INFORMATION:** A general awareness of the innovation and interest in learning more detail about it is indicated. The person seems to be unworried about herself/himself in relation to the innovation. She/he is interested in substantive aspects of the innovation in a selfless manner, such as general characteristics, effects, and requirements for use.

2 **PERSONAL:** Individual is uncertain about the demands of the innovation, her/his inadequacy to meet those demands, and her/his role with the innovation. This includes analysis of her/his role in relation to the reward structure of the organization, decision making, and consideration of potential conflicts with existing structures of personal commitment. Financial or status implications of the program for self and colleagues may also be reflected.

3 **MANAGEMENT:** Attention is focused on the processes and tasks of using the innovation and the best use of information and resources. Issues related to efficiency, organizing, managing, scheduling, and time demands are utmost.

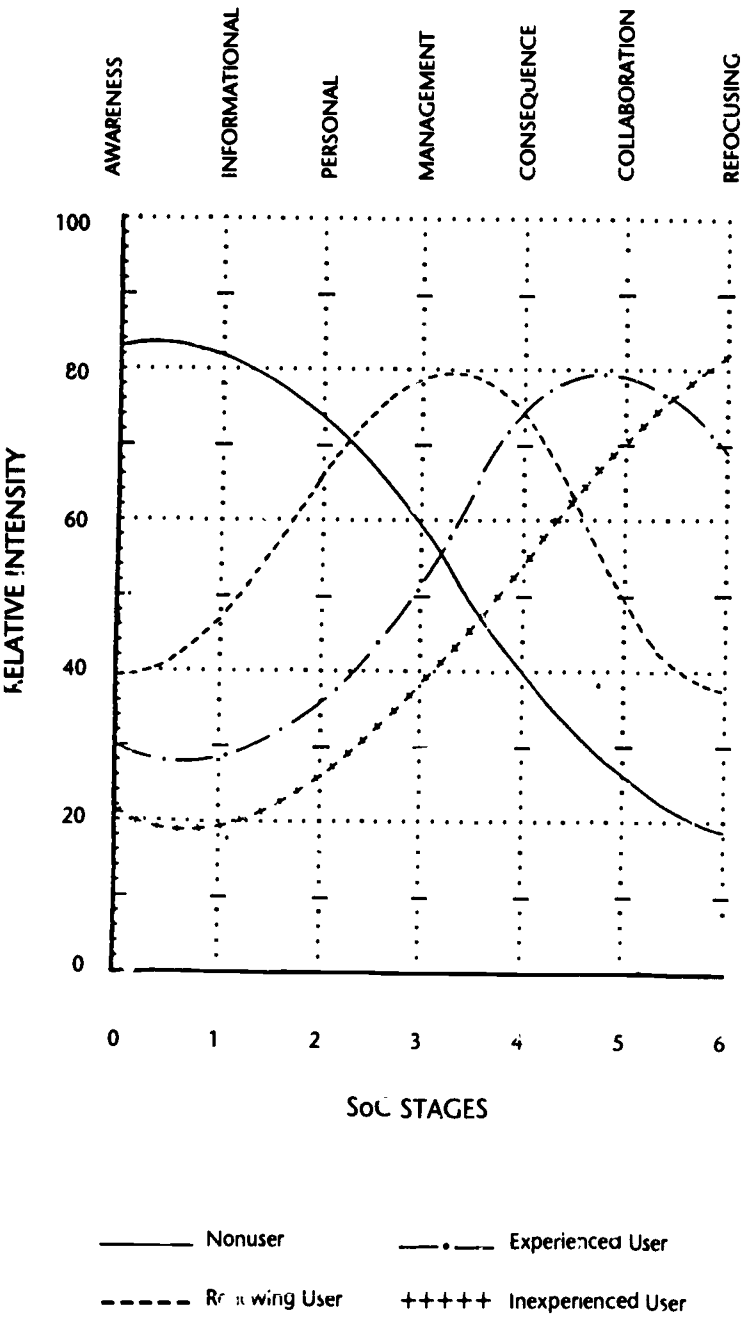
4 **CONSEQUENCE:** Attention focuses on the impact of the innovation on students in his/her immediate sphere of influence. The focus is on the relevance of the innovation for students, evaluation of student outcomes, including performance and competencies, and changes needed to increase student outcomes.

5 **COLLABORATION:** The focus is on coordination and cooperation with others regarding use of the innovation.

6 **REFOCUSING:** The focus is on exploration of more universal benefits from the innovation, including the possibility of major changes or replacement with a more powerful alternative. Individual has definite ideas about alternatives to the proposed or existing form of the innovation.

Original concept from Hall, G. E., Wallace, R. C., Jr., and Dossett, W. A. (1973). *A developmental conceptualization of the adoption process within educational instructions.* Austin: Research and Development Center for Teacher Education, The University of Texas.

Figure 2. Hypothesized Development of Stages of Concern



From Hall, G. E., and Loucks, S. (1978). *Teacher concerns as a basis for facilitating and personalizing development.* Austin, TX. University of Texas.

presented in Figure 2.

The relative intensities of the subscale scores form a curve (known as a profile), which makes it possible to interpret the concerns of individuals or groups. That interpretation's primary focus is on the most and least intense concerns. Figure 2 presents hypothetical patterns of four teachers with differing amounts of experience with an innovation. Thus, the inexperienced teacher would be expected to have the most intense personal and informational concerns; a teacher just beginning use would be expected to have most intense management concerns; and an experienced teacher would be expected to have more intense consequence and collaboration concerns. One can observe the apparent wave motion of the peak (most intense concerns) from left to right. This shows how SoC is related to the teacher's experience and supports the concept that concerns are developmental in nature. It was hypothesized, and data support the idea, that earlier intense concerns must be resolved before higher intensities at later stages can develop. These data are for an ideal situation: Actual concerns data may depart from these curves because lower-stage concerns have not been resolved, or because of some unique aspect of the innovation, or the respondent's perception of his or her role with regard to the innovation.

How Can We Use Concerns Data?

Knowledge of teachers' concerns such as those represented in the profiles in Figure 2 can help direct the supervisor as interventions are planned. The supervisor begins by determining the most intense concerns of users. Interventions are then targeted toward the resolution of most intense concerns. For example, when the most intense concerns are about management, it is appropriate to assist teachers in knowing what materials and equipment are needed for which activities, how they will be supplied, how to distribute and collect them during classroom use, and how to reorganize and store them for future use. Training interventions should engage the teacher in the "how-to" procedures of teaching the program. Providing hands-on training activities that give teachers experience with the skills to be introduced to students helps management-concerned teachers. The supervisor should monitor classroom activity to ascertain the current status of the teacher's management concerns. In the same way, consultation and reinforcement interventions should be planned with management concerns uppermost in mind. These individual consultation activities should focus on those essential day-to-day skills that will help the teacher to solve problems of program use, develop routines, and become organized and systematic with the program and its demands. For a teacher who is concerned about management, a lecture on the philosophy of the new program or its value to children is apt to fall on deaf ears—these arguments are aimed at consequence concerns. Indeed, such a lecture might serve only to intensify lower-stage (personal) concerns.

Teachers who are uncertain of their role in an innovation can be expected to have intense personal concerns, although they may avoid expressing such personal concerns. Therefore, supervisors will want to be sensitive to these concerns and plan interventions that address them. Because the teacher with personal concerns may be easily overwhelmed, a modest intervention agenda is in order. When possible, the materials and equipment should be delivered in person by the facilitator/supervisor, who then should offer assistance. Knowing how to use the materials is an obvious need, but shorter, more frequent training sessions are more appropriate. Finally, the supervisor's frequent and regular monitoring will result in ongoing assessments of the teacher's progress and the change in intensity of personal concerns.

Personal concerns require much supervisor time, attention, and patience. Reinforcing what the teacher is doing with the program is a highly recommended way to initiate a consultation session, because the personal-concerned teacher needs to build confidence. Demonstrating facilitator "care and concern" in the consultation is likely to be very effective with this teacher.

The usefulness of concerns data lies in their ease of collection for local implementation projects. In addition to the Stages of Concern Questionnaire, concerns data can be collected via an informal interview or by having teachers complete an open-ended concerns statement in writing. These procedures may be very valuable to the supervisor when one-to-one facilitation is likely, as would be the case where principals use concerns data to manage implementation within their school.

Describing Appropriate Use of the Program

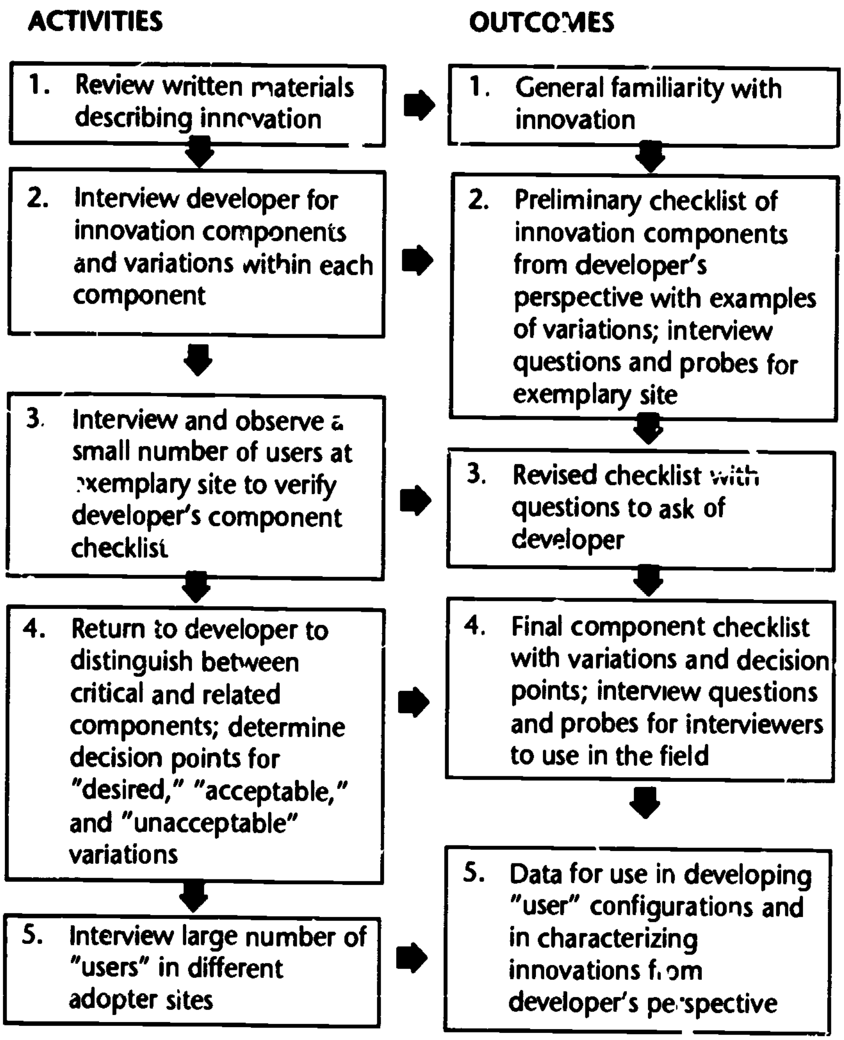
Although the Stages of Concern concept has proven to be helpful in selecting and designing interventions that facilitate implementation, supervisors will recognize that there is more to the implementation process than knowledge of teacher concerns. R&DCTE staff examined the behaviors of teachers in terms of their use of innovations. The results showed that several patterns of teacher behavior emerge as a new program is implemented: Some teachers modify portions of the program soon after adoption, while other teachers do not even attempt to implement the "adopted" program. Still other teachers begin by using only selected parts of the total program. Thus, classroom observations across a school or district can be expected to reveal a variety of patterns of the extent to which the teacher has used the innovation in the classroom. To study the ways teachers use the various parts of the innovation in their classrooms, the concept of Innovation Configuration (IC) was developed (Hall and Loucks, 1981).

The IC can be thought of as a matrix, with the program components (usually materials, teacher's role, and student activities) on one axis and 1–5 variations describing the different ways each component is observed to be used on the other axis. An example is provided in Figure 4. Since the IC is innovation-specific, it must be developed for *each* innovation. The scheme for such development has been reported by Heck, Stiegelbauer, Hall, and Loucks (1981) and is illustrated in Figure 3.

The generalized process for IC development is intended to ensure the inclusion of the developer's viewpoint on the use of each component. This viewpoint usually constitutes a variation labeled "ideal." Other variations are usually designated as "acceptable" and "not acceptable." A goal in developing the IC is to include all variations that observers might actually see in classrooms. In other words, when using the IC one should be able to identify component variations representing any classroom configuration of the innovation. In practice, both the number of components and variations for each must be held to a workable number, usually 8–10 components and 3–5 variations. A simplified example of the matrix format for the IC is provided in Figure 4.

The IC is useful to the supervisor for analysis and decision making. The heavy dark line separates the "ideal" variations from the nonideal variations. This separation enables the science supervisor or facilitator to compare classroom use of the innovation to "ideal" use. The reader will note that more than one variation may be "acceptable" though not "ideal." "Acceptable" variations are listed between the solid and broken lines. All practices to the right of the broken line are "not acceptable."

Figure 3. Procedure for Identifying Innovation Components, Variations, and Configurations.



From Stiegelbauer, S., Hall, G. E.. and Loucks, S. S. (1981). *Measuring innovation configurations: Procedures and applications.* Austin, TX: Research and Development Center for Teacher Education, The University of Texas

Use of the IC

The matrix form of the IC can be the basis for an interview with a teacher, with the interviewer simply marking the variations the teacher reports using. Alternately, the matrix for the IC can be converted into a questionnaire with the variations listed under each component, and teachers can be asked to mark the variation that most closely approximates their use. Beyond this, the IC has a variety of uses.

Choosing and Shaping Interventions. Comparing responses to the relative values of the three kinds of variations ("ideal," "acceptable," and "not acceptable") will suggest appropriate interventions to support the implementation to the supervisor. For example, if teachers were demonstrating learning activities and this was judged "not acceptable," then the supervisor will want to investigate why and target inter-

Figure 4. Science Program Configuration Checklist

IDEAL	ACCEPTABLE	NOT ACCEPTABLE		
Component 1: Units Taught (1) All units and most activities are taught	(2) Most units and activities are taught	(3) Some units are taught	(4) A few selected activities are taught	(5) No units or activities are taught
Component 2: Use of Materials (1) Students are constantly manipulating science materials	(2) Selected students only and the teacher handle the materials most of the time	(3) Typically, the teacher does demonstrations and the students watch	(4) No materials are manipulated by students or teachers	
Component 3: Student Groupings (1) Students work individually and in small groups	(2) Students are kept in 3–5 permanent groups	(3) the whole class is taught as a group		
Component 4: Process/Content Emphasis (1) Science content and science processes are emphasized equally	(2) Science content is given major emphasis	(3) The processes of science are given major emphasis	(4) Memorization of facts and reading about science are emphasized	
Component 5: Assessment (1) All TSP assessment activities are used	(2) Some TSP assessment activities are used	(3) Teacher-made tests are used all of the time	(4) Learning outcomes are not assessed	

ventions to assist the teacher in allowing students to manipulate materials. That might be as simple as unlocking the equipment closet or as complex as helping the teacher learn to manage an activity-based program.

Monitoring Overall Implementation. An IC frequency data summary provides the supervisor with two kinds of information: (1) an overall picture of how the innovation is being operationalized, and (2) a component-by-component breakdown of use along the spectrum from "ideal" to "not acceptable." IC data are also used to examine implementation on a classroom-by-classroom basis for predominant patterns (configurations) of use. The ICs can be sorted according to subgroups composed of individuals with similar usage patterns. For example, these results might show that inexperienced teachers were all having problems with managing the material, or that particular teachers were not involving students in laboratory. A training intervention might then be designed according to subgroup needs. Examination of IC data will reveal that not all teachers are using the program in the same way and that the same interventions are not likely to be appropriate for all teachers.

Focusing District Resources on a Particular Component. By examining the relationships between the variations for each component and student outcomes, the supervisor may decide to concentrate district resources on implementing those outcomes believed to be most desirable. To assess overall implementation, a configuration "score" could be calculated by assigning a value of "3" to "ideal" variations, "2" to "acceptable" variations, and "1" to "not acceptable" variations. One must be aware that to do this is to force ordinal data into interval form. At best, these scores would seem to be only an estimate of implementation.

Communicating Implementation Expectations to Teachers The IC can be used to communicate to teachers the district's expectations about the implementation. The authors' experiences with numerous implementation efforts show that many teachers do not know *how* they are expected to implement the parts of a program. It would seem wise for the supervisor to enlist the help of teachers in deciding which variations are "ideal," "acceptable," or "not acceptable."

Setting Implementation Goals. The IC can be used for classroom, school, or district goal setting—for example, in deciding which components should be implemented first. Subsequently, goals could be set along a time line for implementing other components. Alternately, a district could decide to stage the implementation across variations, with certain variations being labeled "acceptable" during the first year, but "not acceptable" during the second or third year, to encourage the staff to implement in a more "ideal" manner. Thus, the IC can help in planning implementation and serve as a monitoring device for the process. Curriculum facilitators will want to consider goal priorities and plan to move the process toward more ideal variations for each component.

The IC can be a valuable tool for assessing the nature and extent of program implementation. Because the IC can usually be constructed on one or two pages, it is a convenient way to picture the implementation and to gather and summarize implementation data from large numbers of teachers. The reader will, of course, recognize an implicit assumption in the data-gathering process described here: When teachers are asked to report their use, it is assumed that the report is an accurate reflection of the situation. This assumption seems reasonable provided an atmosphere of trust is present. An alternative data-collecting method would be to use the IC as a formal or informal interview or as an observation protocol. Still, an atmosphere of trust will be needed to gather reliable data. IC should not be used to evaluate teachers.

In summary, SoC and IC can be used by science supervisors and other facilitators to monitor, design interventions, and manage the implementation of new programs. These are not the only tools available, but they relate to strategies that are research-based, provide convenient data-gathering strategies, and include theory on which to base interpretations.

An Example of an Effective Change Effort

The tools and procedures outlined above have been used extensively to plan, guide, and monitor a wide variety of implementation and maintenance efforts. One major application was the implementation of a hands-on (no textbook) elementary science program in Jefferson County (Jeffco), Colorado Public Schools (Penick, 1983). Although Jeffco is a large district with 81 schools, the example illustrates the usefulness of the ideas presented here.

Jeffco experienced many of the problems of Anycity during its initial implementation of a modern science program in the early 1970s. The revision of the program had been completed by late 1977 and plans were under way to improve the use of the program in all the schools. At about that time a fortunate collaboration between the district's science supervisory staff and the R&DCTE University of Texas began. Both groups were convinced that another change of materials was not going to solve the problem. This time a great deal of effort and support was going to be provided to help teachers make the changes necessary to use the program as designed.

Most supervisors are aware, as in Anycity, that an inservice or orientation session is necessary before teachers begin to use the program. Typically, this session is conducted in late August or early September just before school begins. Jeffco's science supervisory staff planned a similar approach to the implementation activities, but an introduction to the Concerns-Based approach by the R&DCTE soon produced the more elaborate, long-term plan described here.

The first step was to modify the three-day inservice program planned for the beginning of the school year by rescheduling the sessions three months apart. In this way, the inservice program coincided with the units that the teachers would be using in the weeks that followed. This schedule also allowed for a different approach in each session as participating teachers progressed through the stages of concern while using the new program.

Before the first inservice sessions were held, several important activities occurred. First, the program was approved by the Board of Education, concluding a more than three-year process of piloting and field testing, and a series of review steps in which the pilot program's results were evaluated by the curriculum council, principals, and the superintendent's cabinet. The final step, Board approval, signaled that the process had been completed and the curriculum was now ready for implementation. It further communicated to all administrators and teachers the expectation that the material would be used. The results of this decision were widely publicized to teachers throughout the district, providing them with information prepared to help resolve their first stage of concern (awareness). The results answered the questions: "Do I have to use it?" and "When will it become part of the district program?"

Because of the district size, the schools were divided in three phases and were to begin the new program at different times, approximately a semester apart. In the semester preceding implementation of the program, the participating schools' principals attended a half-day inservice session in which they were given detailed information about the new program, materials, schedule of inservice sessions, and an overview of Stages of Concern. Principals were asked to carry this information back to their teachers and provide them with necessary awareness and information about the new program, inservice dates, the schedule for start-up in their school, the arrival of new equipment, and other logistical details.

As mentioned previously, research on the Stages of Concern has clearly indicated that most concerns at one level must be resolved or satisfied before concerns will emerge at the next stage. Research also shows that awareness, information, and personal concerns are usually most intense for teachers who have not yet become users of the new program or innovation. Management concerns do not develop until after the teacher begins using the new materials. Because of progression, a number of interventions and plenty of time were provided for teachers to work their way through the first three stages of concern before the program began in their school. One of the major interventions designed by the science department was a "pre-inservice" session planned to address inform. onal and personal concerns. These sessions were held for a small number of teachers from one to two schools in a familiar setting (one of their own schools). The meetings were generally informational and informal; a department member or one of the pilot teachers described the new program with a slide tape presentation, outlining the plans for inservice, suggesting schedules for transition to the new materials, and distributing the new teacher's guides. Time was allowed for a question-and-answer session in small groups so that the participants could satisfy their informational and personal concerns.

The first all-day inservice session was originally scheduled a week or two before teachers were expected to begin using the new units in their classroom, but the use of the Stages of Concern Questionnaire during the first phase, as well as other feedback from the participants, indicated that management concerns could be better addressed if teachers first gained some experience in teaching a new unit and encountered the problems of using materials in their classroom. When this timing was used during the second phase, the teachers were much more responsive to the time spent on management techniques in the first session.

The science supervisory staff also anticipated that some of the teachers at the inservice session would have concerns at the consequence stage and would be less involved (concerned) with management issues. To address these teachers' concerns, self-paced instructional modules were made available for part of the inservice session each time. These modules were developed around student-focused topics, such as the application of Piaget's work on science teaching, discussion techniques, and the use of nonclassroom settings for teaching science. On the other hand, small group question-and-answer sessions led by an experienced pilot teac[illegible] were conducted for teachers who still had personal concerns.

In the second and third inservice sessions, held approximately three and then six months later, the instructors still used a hands-on approach to help teachers understand both the management and content of the new units, but more time was provided to deal with higher stages of concern such as consequence and collaboration issues. At one point before the first inservice session, and again several months after that session, Stage of Concern Questionnaires were administered to all teachers. The profiles were shared with all teachers and an interpretation provided. Although the data was primarily used to monitor the progress of the teachers and the impact of the inservice sessions, teachers who still had intense personal and information concerns were the first recipients of the "comfort and caring" visit by a member of the science department. Typically, these visits were not scheduled to observe teachers teaching science but were arranged to occur during their planning sessions, lunch, or before or after school to help teachers deal with problems and concerns that they still had about the new program.

Shortly after the three inservice sessions were completed for all schools, work began on two other major projects related to the program's implementation. The first of these was the development of a set of Innovation Configurations, or Key Features, as they were known in Jeffco. The Jeffco Key Features also covered some additional items usually referred to as implementation requirements, which included facilities, budgets, inservice preparation of teachers, teaching behaviors, classroom management, grouping of students, and so on. The Key Features were initially designed to be used by a third party to evaluate the degree to which the program was being successfully implemented two years after the inservice was completed. This proved to be a very successful, if expensive, means of evaluation. The use of the Key Features soon evolved into a productive school improvement effort called the Science Instructional Improvement Process (Melle and Pratt, 1981). In this process, a principal and a member of the district science department, with the support of a trained teacher from another school, spent about 30 hours throughout the school year working with the school staff to improve the quality of the science program delivery. Although the process eventually included an assessment of each Key Feature, it was carefully carried out in a collaborative, supportive way to help teachers improve their ability to teach elementary science.

The second major activity developed shortly after the initial implementation was the creation of a criterion-referenced test to measure student achievement in both process and content covered in the new program (Pratt, Winters, and George, 1980). The test was designed for two basic purposes. The first was to provide feedback to the school staff on their effectiveness in delivering the program. This type of data provides much needed information for teachers with consequence concerns about the level of their students' achievement. The second purpose was to communicate the importance of elementary science to all members of the school district's staff.

Ten years after the initial inservice, many of the original activities are still being carried out. Three full days of inservice sessions are provided for teachers new to the district and those changing grade levels. "Comfort and caring" is a regular part of the district science department activities, with each school being visited on the average of two out of every three years. Technical information is provided to all teachers and principals through personal visits, phone calls, and a regular newsletter. The Key Features (IC) are used in the Instructional Improvement Process with five or six schools per year. In addition, the Key Features are circulated among all elementary staff members as a means of communicating what a successfully implemented program is like in each school.

The results have been very positive. Data collected by the Texas R&DCTE (Loucks and Melle, 1980), reports from the district's evaluation department (Darnell, 1979), observations during the Instructional Improvement Process, general observations of principals, and the report of the NSTA Search for Excellence team (Penick, 1983) all indicate that the program is in place in virtually every classroom in the district.

How did Jeffco avoid the pitfalls of Anycity and the many other school districts across the country who have reported the demise of the new programs of the 1960s and 1970s? Several lessons can be learned from this case study:

1. The improvement effort was not viewed as simply a change of materials that were to be "installed;" instead, *the improvement was seen as both an improvement of materials and a change in the beliefs and behaviors of teachers.*

2. The implementation process takes years, not weeks or months. Implementation should be viewed as only the first step of a long-term plan for maintenance and institutionalization of the program. *Ongoing assistance, support, and maintenance never ends.*

3. *Strong, continuous leadership committed to the program is needed at the central office and local school levels.* The principal is obviously indispensable in this role, but a second person within the school or the central office or sometimes outside the district can play a very important role.

4. *The district has strong expectations and commitment to the program* which are expressed in many ways: through Board of Education decisions, district policy, instructional time allotments for science, evaluation procedures, budget commitments, administrative decisions, testing programs, etc.

It may be tempting to read through this case study to find one or two key practices that will make the difference between the successful and unsuccessful implementation of the program, but evidence indicates that a single activity seldom has a significant effect when considered alone. The problems of implementation, as well as all school improvement efforts, must be considered systematically by creating a series of activities that will intervene on all parts of the system over a considerable period of time. New materials can be easily purchased and delivered, but their effective use calls for behavior and attitude changes by the teachers. This requires considerable time, effort, and support on the part of the science supervisors and many other leaders in the system if the change is to be successfully made.

References

Archer, N. S. (1980). Installing a new curriculum: Observations and recommendations. In *Some process curricula and their installation* (pp. 56–58). New York: Eastern Regional Institute for Education.

Arons, A. B. (1983). Achieving wider scientific literacy. *Daedalus, 112*(2), 91–122.

Carlson, R. O., et al. (1965). Barriers to change in public schools. *Change process in the public schools* (3–8). Eugene, OR: Center for the Advanced Study of Education Administration.

Darnell, D. (1979). *The extent of implementation of the Jefferson County schools revised science program.* Lakewood, CO: Jefferson County Public Schools.

Fuller, F. (1969). Concerns of teachers: A developmental conceptualization. *American Education Research Journal, 6*(2), 207–226.

Hall, G. E., & Hord, S. M. (1987). *Change in schools: Facilitating the process.* Albany, NY: State University of New York Press.

Hall, G. E., & Hord, S. M. (1986, April). *Configurations of school-based leadership teams.* Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Hall, G. E., & Hord, S. M. (1985). High school change: Boarding house or hotel restaurant approach? *The Northeast Perspective, 1*(6), 1–2, 7.

Hall, G. E., George, A. A., & Rutherford, W. L. (1979). *Measuring stages of concern about the innovation: A manual for use of the SoC questionnaire.* Austin, TX: The University of Texas.

Hall, G. E., and Loucks, S. (1978). *Teacher concerns as a basis for facilitating and personalizing development.* Austin, TX: Unversity of Texas.

Hall, G. E., & Loucks, S. F. (1981). Program definition and adeption: Implications for inservice. *Journal of Research and Development in Education, 14*(2), 46–58.

Hall, G. E., Rutherford, W. L., Hord, S. M., & Huling-Austin, L. (1984). Effects of three principal style school improvement. *Educational Leadership, 41*(5), 2[illegible]–29.

Hall, G. E., Wallace, R. C. & Dossett, W. A. (1973). A *developmental conceptualization of the adoption process within educational institutions.* Austin, TX. Research and Development Center for Teacher Education, The University of Texas.

Heck, S., Stiegelbauer, S. M., Hall, G. E., & Loucks, S. F. (1981). *Measuring innovation configuration: Procedure and application.* Austin, TX: The University of Texas.

Hord, S. M., & Hall, G. E. (1987). Three images: What principals do in curriculum implementation. *Curriculum Inquiry, 17*(1), 55–89.

Hord, S. M., & Diaz-Ortiz, E. M. (1986, June). *Beyond the principal: Can the department head supply leadership for change in high schools?* Paper presented at the International Research Seminar on Internal Change Facilitators, Center for Educational Policy and Innovation, The University of Leuven, Belgium.

Hord, S. M., & Hall, G. E. (1982, March). *Procedures for quantitative analysis of change facilitator interventions.* Paper presented at the annual meeting of the American Educational Research Association, New York, NY.

Hord, S. M., Hall, G. E., & Zigarmi, P. (1980, April). *Anatomy of incident and tactic interventions: Dimensions and design.* Paper presented at the annual meeting of the American Educational Research Association, Boston, MA.

Hord, S. M., & Huling-Austin, L. (1986). Effective curriculum implementation: Some promising new insights. *Elementary School Journal, 87*(1), 97–115.

Hord, S. M., & Murphy, S. C. (1985, March). *The high school department head: Powerful or powerless in guiding change.* Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Hord, S. M., & Rutherford, W. L. (1985). Dogs can't sing? Good news, a dash of optimism and high school change. *The High School Journal, 69*(1), 16–20.

Hord, S. M., Stiegelbauer, S. M., & Hall, G. E. (1984). How principals work with other change facilitators. *Education and Urban Society, 17*(1), 89–109.

Loucks, S., & Melle, M. (1980, April). *Implementing a district-wide science curriculum: The effects of a three-year effort.* Paper presented at the annual meeting of the American Educational Research Association, Boston, MA.

Louis, K. S. (1986). Reforming secondary schools: A critique and an agenda for administrators. *Educational Leadership, 44*(1), 33–36.

Melle, M., & Pratt, H. (1981, April). *Documenting program adoption in a district-wide implementation effort: The three-year evolution from evaluation to an instructional improvement plan.* Paper presented at the annual meeting of the American Educational Research Association, Los Angeles, CA.

Penick, J. (Ed.) (1983). *Focus on excellence: Elementary science.* Washington, DC: National Science Teachers Association.

Pratt, H., Melle, M., Metzdorf, J., & Loucks, S. (1980, April). *The design and utilization of a concerns-based staff development program for implementing a revised science curriculum.* Paper presented at the annual meeting of the American Educational Research Association, Boston, MA.

Pratt, H., Winters, S., & George, A. (1980, April). *The effects of a concerns-based implementation plan on the achievement of elementary science students.* Paper presented at the American Educational Research Association Annual Meeting, Boston, MA.

Rutherford, W. L. (1985). School principals as effective leaders, *Phi Delta Kappan, 69*(1), 31-34.

Robert K. James, a science educator, is the author of numerous papers and articles on the implementation of science programs. He is the director of the Center for Mathematics and Science Education at Texas A&M University and the Texas Alliance for Science Technology and Mathematics Education. Before coming to A&M he was professor of science education at Kansas State University from 1969–1984.

Shirley M. Hord is senior development associate at the Southwest Educational Development Laboratory in Austin Texas, where she coordinates activities related to educational change and school improvement. She is coordinator of a multi-year rural school improvement project in the Lab's five-state region.

Harold Pratt is executive director of Science and Technology for Jefferson County public schools in Golden, Colorado. He has been active in curriculum development and implementation at the national and local level. He is past president of the National Science Supervisors Association.

Grant Seeking: Searching for the Pot of Gold

10

KENNETH R. MECHLING
CLARION UNIVERSITY

We have all heard the ancient adage that the love of money is the root of all evil. But from the perspective of a science supervisor, we might agree more with Mark Twain's paraphrase, "the *lack* of money is the root of all evil."

There are many things in education we can't do because we can't afford to do them. The lack of money is often the major stumbling block to acquiring needed supplies and equipment, providing expensive teacher inservice, or revamping an outmoded science curriculum. With more dollars we could tackle these and other challenges languishing from the school's seemingly perennial economic depression. If only we could follow the fabled rainbow to the pot of gold.

While one might logically expect the school district's budget to support all our science education needs, our real world experience tells us that's unfeasible. Seldom do we get all the funds to do what needs to be done. As supervisors, we accept the money we are given from the school budget with either satisfaction or veiled disgruntlement, or look elsewhere for help. Following are a few examples of schools that looked elsewhere:

- A school in Pennsylvania needed more hands-on science experiences in its elementary schools. The science supervisor developed a grant proposal to provide teacher inservice and supplies for teaching electricity, magnetism human biology, and other units. The project was funded by the Education for Economic Security Act.

- Science teachers in a Florida school district felt left behind by advances in science and technology. Their science supervisor contacted a regional high technology industry for help. The corporation now funds inservice programs held in the corporate board room, bringing together industrial scientists and district teachers to examine technological advances and their impact on society. The corporation hosts the teachers, picks up the cost of substitutes, and is paying for upgrading science equipment in the district's science classrooms.

• A school system in Colorado is developing a year-long middle school/junior high school life science program which emphasizes understanding and care of the human body. Developed in conjunction with an area university and local physicians, the project will develop life science curriculum materials and link with school health programs. The National Science Foundation (NSF) will provide $590,000 for this three-year effort.

• Staff development in science education was the target for a Connecticut school system. Professional growth opportunities were provided for science and educational content weaknesses and interests. Research findings from teaching methodology and learning theory were applied to science teaching and supervision, and school science personnel learned to use the computer as a laboratory instrument. $266,000 was granted by NSF for a variety of staff revitalization activities.

Similar success stories abound. Literally thousands of school districts across the United States augment their science budgets with financial support from grant-making agencies. Yours could be one of them, if you are willing to invest the time and effort necessary to seek grants.

Contrary to popular belief, successful grant seekers don't start by writing a proposal. Rather, they consider their needs. They find out who has the money. They make contacts. They seek information. They study funding guidelines. They make plans, and then they write the proposal. If grant seeking were compared to baking a five-tiered wedding cake, writing the proposal would be the top layer. Everything else provides the foundation upon which the proposal is built.

Grant seeking is not for the faint-hearted. It demands time. It requires hard work. Failure is common. But even though success is not guaranteed, the odds certainly favor a science supervisor who has an important need, who has done the requisite homework, who can write clearly, and who is persistent. If you are ready to follow that rainbow, read on for some helpful hints which could lead you to the pot of gold.

A Spectrum of Funding Opportunities

There are many rainbows and many pots of gold—if you know where to look. Consider federal, state, and local governmental agencies. Consider organizations including businesses, industries, and foundations. Consider people and groups in your own backyard—many give grants in dollars or services for school science. Begin by considering an old familiar source, NSF.

Review NSF's programs and consider initiating projects that connect your school with colleges, universities, museums, professional societies, or other educational institutions. Create connections that will benefit your school's science programs. Contact NSF for descriptions of their programs and the guidelines of those that interest you.

Another important pot of gold is the Education for Economic Security Act (EESA), the source of Title II funds. This federal program is an excellent source of funds for schools or consortia of schools interested in providing creative staff development experiences, ranging from seminars on science-technology-society to workshops on science for elementary and secondary teachers. References and supplies purchased for teacher inservice programs often travel back to the classrooms with the teachers. Contact your state department of education for guidelines and copies of their Request for Proposals (RFP) forms.

Many states—Pennsylvania, for example—have grant programs aimed at science teacher education, equipment acquisition, curriculum development, and science leadership training for school administrators. Personal contact with a Pennsylvania state legislator in 1983 has resulted in more than $30 million in state grants for science and technology education. Contact your representatives or senators and ask about grant opportunities applicable to science education. Get them interested in your ideas. Ask for their help, and be willing to help them.

Other sources of funding include grant programs by businesses, industries, and foundations. These groups are especially good prospects right now because of the attention focused on science education in recent years. Try hometown or regional organizations. Look to chemical industries for chemistry education grants, to agricultural industries and health-related businesses for grants for life science programs, to mining companies for earth science program support, and so on.

Of course, don't overlook the obvious—local government-related agencies, parent-teacher associations, service clubs like Kiwanis, Lions, or Rotary, interest groups like Audubon Societies, Sierra Clubs, or conservation organizations, or even our own schools. More and more schools are beginning small competitive grants programs.

Procedures for submitting a proposal to grant making agencies vary considerably. Governmental agencies such as NSF or state governments administering the EESA's Title II funds have very specific guidelines for preparing proposals. A personal contact with a grants program officer may not be necessary for NSF or EESA funding consideration. But personal contact will be necessary for funding consideration by private foundations, corporations, industries, and local groups. In fact, such organizations seldom fund unsolicited projects from individuals unknown to them. To increase your funding chances, become acquainted with the grants officers or have someone within the organization introduce you and your ideas. Having an advocate can enhance the chances of your proposal receiving a favorable review.

Someone, somewhere, may supply the funds for doing what you, the science supervisor, needs to have done. But remember the first rule of grantspersonship: You have to ask. Whom do you ask, and how? Begin by considering the information sources at the end of this article for ideas.

A Rainbow of Possible Projects

Selecting and refining a project proposed for funding can be difficult. Yet every successful grant proposal begins with a need which, if met, will likely result in substantial improvement in a program.

If you're new at seeking grants, it's probably a good idea to have three or four well-defined needs. Perhaps your science curriculum is designed to teach higher-level thinking skills and science processes, but your evaluation system is still measuring memorization and rote. Building a new evaluation system takes time and money. Or perhaps your elementary schools have no hands-on science because of lack of teacher education and science supplies. Or perhaps increased state requirements for science have mandated more science be taught to students who have historically opted for less. Or maybe you'd like to develop a science-technology-society course or increase microcomputer interfacing in science labs. All of these are problems with concomitant needs that can be addressed with a grant proposal.

The problem you select to address will be governed by its perceived importance to you and by the grant-maker's potential interest in that particular problem. Submitting a grant proposal for science supplies to a grantor that funds only teacher education is, of course, a waste of time. You will need to identify clearly and convincingly what the problem is and how funds from the grantor could make a difference in your school's science program, all the while advancing the interests of the grant-making agency.

Some typical science education projects which have been funded with outside funding include:

- acquisition of five Apple IIe microcomputers plus interfacing equipment and supplies for all science labs in a school district
- providing summer salaries for a ten-person science committee engaged in planning needed improvements in a school's science program

- establishing and stocking science resource rooms in all eighteen elementary schools in a district
- funding the participation of all secondary science teachers in one state, regional, or national conference for science education
- funding the participation of all middle/junior high school students in a week-long marine education program at a coastal marine science center
- funding a bilingual science program for Hispanic students
- equipping a newly completed greenhouse for use by elementary school children
- developing school nature trails
- producing television science programs for primary school children and related teacher activities

Whatever your project, be prepared to modify it to fit the guidelines and interests of the grant-making agency. If you can't make it fit while satisfying the integrity of your need, seek other funding sources.

Getting on the Right Wavelength for Proposal Writing

Once you have some project ideas and know where the grant gold is hidden, you're ready to begin preparing the proposal. But keep in mind that grantors vary in their proposal requirements. Some RFPs have guidelines which specifically spell out the proposal procedures you are to follow, from the number of pages to the submission date. Others are more general, painting proposal requirements in the broadest of strokes. While you may not yet be ready to write the actual proposal, you can begin preparing individual sections, eventually putting them together according to the grant maker's guidelines. Often, however, private foundations do not provide guidelines. Selecting the components of your proposal will be up to you. Whether or not guidelines are available, the following components are almost universally applicable.

Introduction

The introduction is your chance to introduce yourself to the grant-making agency and establish your credibility as someone who can do successfully undertake the proposed project. Capture their interest with a good opening line or appropriate quote. Convince them that you can do the project better than anyone else.

Needs Statement

Document your needs. No one will give you money if you don't need it. Produce convincing evidence. Conduct a survey. Include testimonials. Reference the literature. Show that you recognize the need, that it fits the interest of the grantor, and that if the need is successfully met through project funding, both you and the grantor will benefit.

Objectives

Objectives tell who is going to do what, when, how much, and how it will be measured. Your project is a means to an end. The objectives specify that end. Tell what you will accomplish.

Methods

In this section you spell out how the objectives will be accomplished. You will need to detail your project activities, your reasons for selecting them, why you sequenced the activities the way you did, who will do the work, who will participate, and over what period of time all this will occur. Ordinarily, the *Methods* section is the longest section of the proposal, though it may be limited to two or three pages even in the most lengthy proposal. You will need to present the details of your project in a clear, logical, and coherent manner. It must make sense to the funding agency.

Evaluation

The grant maker will be interested in knowing if your objectives have been met by the methods you chose. They will seek measurable evidence that their money has been well spent. They will be interested in "product" evaluation (assessments of the extent to which your project has met its objectives) and "process" evaluation (assessments of whether you carried out your project as originally planned). The *Evaluation* section of a proposal has become increasingly important to grant makers. They now often require that evaluations be conducted by third-party, impartial evaluators. The Science Education Research and Evaluation Laboratory (SEREL) at the University of Georgia is one such evaluation agency. Even if evaluation is not required in the proposal guidelines, include it to convince the grantor that you know where you are going and have established criteria to measure your success.

Future Funding

Grant-making agencies are interested in exemplary project models with significance beyond the local scene. Seldom does a grantor desire to keep funding any project on a long-term basis. They lean toward projects that will eventually become independent. In this section you will need to present your needs and plans for future funding. Show them that, while you will need their help at the beginning, your project will eventually stand on its own.

Budget

While other parts of your proposal may get careful review, you can expect the budget to get extraordinary scrutiny. After all, you are asking for the grantor's money. You should estimate as closely as possible, to the nearest dollar, the funds needed to conduct your program. Common items include salaries, fringe benefits, supplies, travel, consultants, equipment, and so on. Most proposals are strengthened if a portion of the budget needs are donated from other funding sources.

Many grant makers have detailed budget-writing requirements. Others let you decide on the format. In either case you should be prepared to present your budget request broken down into two general categories, personnel costs and non-personnel costs. Expect to provide a detailed explanation of each budget item.

Appendix

Appendices are "catch-alls". They follow the other sections of the proposal and may include information of lesser importance or too bulky to be included elsewhere. Examples are staff vitae, letters of support, and detailed program schedules. Avoid lengthy appendices. If the information is not germane to the proposal, forget it.

Summary

Although the *Summary*, or *Abstract* as it's sometimes called, will appear at the beginning of the proposal, prepare it after you've completed everything else. It should clearly and concisely identify who you are, the reason for the proposal and the needs it will meet, your objectives, an overview of how you will conduct and evaluate your project, and the amount of funding requested from the grant maker. Don't underestimate the importance of this brief section: The grantor may use it to determine whether there is a need to read further.

These, then, are the major components of most proposals. While detailed descriptions on how to write each of these sections are available in many books, periodicals, and other references, keep in mind that most proposals are expected to be brief, from three to fifteen double-spaced pages. You can collect more information than you use, but pare your proposal to the minimum needed to get your story across. There is a suspicion, not without foundation, that if grantors groan when they see the length of your proposal, it's likely to end up on the reject pile.

Final Reflections

Following are several tips that could make the difference between finding the gold or just an empty pot.

• Know your grantor. Learn as much as you can about the grant-making agency, especially their funding interests and their expectations for projects. Find a prospective grantor whose interests match your needs, and [illegible] them clearly in your proposal.

• Personal contacts can help. Many grantees are successful because they have established rapport with the grant maker through courteous contacts by letter, telephone, or personal visits. Making a favorable impression never hurts your chances.

• Let the right hand know what the left hand is doing. As you begin to prepare for your proposal, tell your school district supervisors and administrators about your ideas. Seek their support. It's likely that someone in your school, your superintendent or their representative, will need to sign your proposal as the responsible school officer. Keep them informed of your progress.

• Follow the RFPs or guidelines to the letter. If you think you can single-space the narrative when the guidelines say double-space, or submit the proposal on March 16 when the RFP says March 15, your proposal probably doesn't stand a chance for support. Not following the guidelines exactly is a major cause of proposal rejection.

• Learn the criteria for proposal evaluation. Many grant-making agencies have very specific criteria for evaluating proposals. Additionally, sections may be weighted to reflect their perceived importance. For instance, the Needs Statement might be weighted 20 percent while the Evaluation Plan is weighted 10 percent. It behooves grant seekers to learn the criteria and weights used to evaluate proposals, and tailor their proposals to meet each criterion. The grant maker describes what they want. The grant seeker delivers.

• Avoid typos and coffee stains. Your final proposal should be clean, neat, and error free. Have several people proofread your final copy to ensure accuracy.

• Be brief. Most successful proposals are short, often in the range of two to five pages. Grantors expect clarity. Long-winded dissertations do not win friends. The $30 million Pennsylvania science and technology grant program mentioned earlier began with a proposal of three pages.

• Resist budget padding. Be realistic in your budget requests. Grant makers want the projects they support to succeed, and they expect cost-effectiveness. It is not uncommon for them to suggest that funds be added to line items where shortfalls may exist. In any case, be prepared to discuss, even negotiate, the budget if the grantor deems the proposal worthy of support.

• Persistence pays off. If your proposal is not funded the first time it's submitted, find out why and make improvements. If appropriate, submit the improved version to the same grant-making agency or find a new one. Some successful grant seekers have resubmitted their repeatedly improved proposals as many as five times before they hit pay dirt.

• Establish a good track record. Once your project is well underway, highlight your successes through published reports, press releases, and presentations at professional meetings. Carrying out a project successfully, having it pass muster with professional peers, and promoting it are likely to contribute to new grant opportunities.

Grant seeking is a challenging process. The incentive is the opportunity to initiate worthy projects that are beyond our schools' funding capabilities, projects which strengthen science education for the students and teachers in our schools. The pots of gold are there. We need only follow the brightest rainbows. Begin planning that proposal now!

Bibliography

The Art of Writing Successful R&D Proposals
by Donald C.Orlich and Patricia Rend Orlich

Redgrave Publishing Company
Docent Corporation
430 Manville Road
Pleasantville, NY 10570

$11.25

Provides an excellent set of guidelines for persons interested in converting ideas into successful grant proposals. Don Orlich is a well-known science educator who has taught courses on proposal writing.

Developing Skills in Proposal Writing
by Mary Hall

DCE Media Publications
P.O.Box 1394
Portland, OR 97207

$15.00

A readable, practical guide to proposal preparation. Appendices include good examples of review criteria by government, private foundation, and corporate granting agencies.

Directory of Awards

Forms and Publications Unit
Room 232
National Science Foundation
Washington, DC 20550

Free

NSF has numerous directories of awards. Ask for one from the most recent year. Included are lists of awards, titles, grantees, brief project descriptions, award amounts, and lengths of duration. An excellent resource.

Federal Register

Superintendent of Documents
U.S.Government Printing Office
Washington, DC 20402

$50.00 per year

A weighty, detailed description of all the rules and regulations created by federal agencies, including information on newly-implemented science education grant programs as they are approved by Congress. Published daily.

Foundation Fundamentals: A Guide for Grantseekers
(3rd Edition)
by Carol Kurzig

The Foundation Center
79 Fifth Avenue
New York, NY 10003
(212) 620-4230

$9.95

A good "how-to-do-it" guide for beginning grant seekers.

The Foundation Director

The Foundation Center
79 Fifth Avenue
New York, NY 10003
(212) 620-4230

$85.00

A state-by-state listing of more than 4,000 foundations that give more than $100,000 annually. Describes the foundations purposes and activities, contact persons, and application procedures. Note: The Foundation Center is an excellent one-step resource for information on foundation grantseeking, including computer searches. Request a list of their publications and services.

Grants for Science Programs

The Foundation Center
79 Fifth Avenue
New York, NY 10003
(212) 620-4230

$40.00

Lists about three thousand grants made on a state-by-state basis in 1984-1985, including about $5 million for elementary and secondary education. A good source for identifying grantmakers and the kinds of projects funded.

Grants: How to Find Out About Them and What to Do Next
by Virginia White

Plenum Press
233 Spring Street
New York, NY 10013
(212) 620-8000

$24.50

The title tells the story. A comprehensive description of grant writing, A to Z.

Kenneth R. Mechling is chair and professor of biology and science education at Clarion University of Pennsylvania. He has written and directed science and technology grants worth over $40 million. He has received numerous honors, including NSTA's Distinguished Service to Science Education, Pennsylvania's Honor Roll of Fellows, and others.

What Is the Science Supervisor's Role in Staff Development?

Curriculum Development and Staff Development 11

MARY BLATT HARBECK
DISTRICT OF COLUMBIA PUBLIC SCHOOLS

Most science supervisors in professional positions find themselves primarily responsible for two major functions, curriculum development and staff development. These responsibilities are interconnected, and each should be undertaken with the implications for the other firmly in mind. Because curriculum development influences the content and format of staff development, it will be considered first.

Curriculum Development

Curriculum development is a continuous, ongoing revision of content that reflects new ideas about what students should learn. Today, many communities want an educational program planned specifically for their own students. Although some curriculum plans are centered around chosen textbooks, other districts provide a curriculum guide to describe the goals, set the objectives, and list the resources available for augmenting the textbook-based instruction. There are often broad guidelines providing a framework for local curriculum efforts by the state department of education. In some school districts or schools, usually the larger ones, a complete curriculum is developed locally and independent of any textbook series. Science supervisors are often expected to assist in choosing the form of curriculum development to be done, and are expected to plan and administer the actual work of producing curriculum guides.

If the curriculum is to be based on selected textbooks and commercially available materials the science supervisors should devise the work plan by considering, at least, the following questions:

1. Who chooses the textbooks for each grade level course?

This is generally done by committees of teachers, with a parent, administrator, and teachers' association or union representative also invited to give a balanced viewpoint.

2. What criteria are to be used for rating each textbook or series?

In addition to checking the scope and depth of content against course goals, committees judge the quality, accuracy, degree of bias, attractiveness, and durability found in each book. The supervisor may wish to construct a worksheet which the committee members can use to score or rate competing texts.

3. When shall the work be done? How often?

A timetable is necessary to assure that the deadline for submission will be met. Unless a comprehensive plan has been implemented by the school district for all subject areas, the science supervisor should propose a plan that includes a timetable for text and instructional materials to be: (1) submitted for review by the publishers/vendors, (2) examined and rated by committee members individually, (3) finally rated by collective agreement of committee members, (4) listed in proper format for submission, and (5) submitted to the appropriate office or staff person.

If textbooks are used to constitute course outlines, it is necessary to have a regular schedule for textbook list revision, especially in science, where content is quickly outdated. A five-year cycle is ordinarily used, but, from a curriculum point of view, a continuous cycle is highly desirable. Unfortunately, the economics involved may well make such a plan prohibitive.

If a given course offering is to serve all students reasonably well, then supplementary materials will be needed. Most textbooks include everything the author can envision, but textbook authors can never foresee exactly what a particular classroom of students needs. Textbooks are designed to attract potential customers so that a profitable number of the books can be sold. So it is unfair to leave the impression with teachers that the course should explore every topic in the chosen books, or that the chosen books should fill all needs.

In response to the national and local concern about improving science education, a given community school board may direct the school superintendent to provide a locally designed curriculum to serve the students and assure increased success in the educational system. Conversely, the local school administration may offer such a plan to the community as a way of expressing the mission or goal of the school system. In this type of curriculum development, textbooks are no longer the basis of instruction, but stand as reference materials for students.

Once the decision to write an independent curriculum has been made, the science supervisor will be expected to take responsibility for the science portion of the project by seeking solutions to the problems in the areas discussed below. These decisions may be individual, but are more likely to be made by the steering committee or task force working on the planned curriculum revision.

Philosophical Considerations

What is the philosophical base from which the curriculum is to be developed?

The answer to this is not to be confused with those well-intentioned doctrines found at the beginning of most education documents. It is, rather, the decision about what outcomes are planned for and expected as a result of the curriculum revision. The goal statement(s) should be expressed in terms of performance; in this way, student progress becomes a measure of evaluation for the effectiveness of the curriculum and its implementation. As the philosophy becomes part of a systematic approach to curriculum development, it will be revised many times before a final version is ready.

The goals are often stated in terms of what the successful graduating seniors will be able to do. It may state the competencies to be achieved by students at several steps along a K–12 continuum. The same rules apply even if only one grade level or course is being revised.

Community input is an important part of goal setting. A tentative list of goals is sometimes developed by teachers and offered to P.T.A., church groups, and civic groups. Members of these groups add to, delete from, and prioritize the goals. A consensus is reached by combining the feedback from the groups. This produces a feeling of ownership for everyone which will be profitable later in the implementation stage. Teachers' union or professional association members in the district should be represented on all committees. Curriculum guides are more likely to be used by teachers who feel that they had input into them.

What shall be the focus of instruction?

Competency-based curriculum is focused on the acquisition of skills by students, with the understanding that skill development includes the gaining of knowledge. Students cannot learn a static "organized body of knowledge" (a former definition of school science) because our knowledge in science changes and expands so quickly. A curriculum that can convey learning skills which can be applied to new knowledge is the most valuable. The content students use to practice their skills is more useful if it concerns current problems in society and technology rather than traditional science activities familiar in textbooks and laboratory manuals for decades.

Is the curriculum to be student-centered or text-centered?

If students are to be held to required competencies for graduation or for promotion from one grade to another, then it is necessary to assure that the opportunities to learn those skills are provided in the courses of study. If the instructional objectives are written to specify student performance, they allow for criterion-referenced evaluation of learning. The provision for such measurable learning is attractive to students, teachers, and parents alike. No one is forced into guessing what the exact learning tasks are. Student-centered learning allows the use of textbooks as reference materials when they are needed. It also facilitates the use of other instructional aids: videotapes, computer software, films, magazines, and so on. In the hands of imaginative teachers the possibilities are endless. Whichever style is followed, the curriculum guide should be a compendium of effective ideas to help teachers begin with instructional planning, not a canon to be followed verbatim.

How will the efficiency and effectiveness of the curriculum be evaluated?

Plans should be made to field test new curriculum guides. Often this is done by publishing preliminary draft versions which teachers use and critique, with the final version being published the following year. A formal evaluation is also possible, given enough time and money. By collecting data on actual student achievement on each strand or section, a measure of effectiveness can be made. Any part of the work that falls below the chosen standard must then be rewritten to improve the likelihood that students will achieve the stated objectives.

These methods of evaluation and other questions are usually considered and planned for at the beginning of a curriculum writing venture. The advisory or steering committee can then determine tentative answers so that the plan can go forward.

Logistical Considerations

What is the expected timetable?

Developing curriculum and putting it into effective use takes longer than is commonly supposed. One effective time line is to plan a three-year sequence of events. In the first year writing committees are formed and put to work, goals are set, and the philosophy or model to be used is determined. Teachers and the community are made aware that changes are being planned and told as much as possible about them. This year of "awareness" does not require any changes to be made: it serves to sensitize the curriculum users and gives them the opportunity to participate in the process and ask questions. The first drafts are made ready for pilot use in the second year.

Early in the second year the inservice sessions are begun for those teachers who will pilot test the materials. Administrators should also attend some inservice sessions, so that they are prepared to provide the support teachers need as the curriculum is tested. This year of "understanding and commitment" is a time of evaluating and revising the written product, preparing people to use it, and planning the implementation. Thought will be given to how the new curriculum will affect grading, scheduling, standardized testing, report cards, and promotion policies. The curriculum steering committee usually makes recommendations on these areas; the recommendations are then submitted to the superintendent so that appropriate policies for each can be established. Field testing may also begin during the second year.

The third year, sometimes called the year of implementation, is a time of full-fledged pilot use, application of formal validation procedures (if desired), and collection of feedback from the teacher and student users. Writing teams will work on needed revisions, and the final format for documents and any needed policy changes are begun. Toward the end of this year final documents will be printed and disseminated, needed policy changes will be instituted, and full implementation is underway. For the foreseeable future a continuing cycle of evaluation and revision will keep the curriculum viable.

This would seem to be a long, drawn-out procedure, but it should be remembered that gradual changes allowing for the involvement of all concerned parties are more effective in bringing about lasting improvements. The pride of ownership in the system helps to encourage teachers to adapt and work toward specific goals for instruction.

How will the curriculum writing be done?

Writing teams are usually composed of teachers who have been chosen for their creativity, enthusiasm, and successful teaching experience. The science supervisor will need to work closely with the team to edit and critique the work. Very successful teachers may not be able to express their thoughts well in written form. The writers may need training and guidance in how to follow the model established by an advisory committee. A curriculum guide usually includes objectives expressed in performance terms, learning activities, strategies, and techniques, and assessment tasks for evaluating the effectiveness of lessons. It may also include scope and sequence charts, time allotments, reference material lists, equipment lists, pretests, and post-tests. The supervisor may need to do the editing and page layout for the camera-ready copy. The timetable for writing, field testing, and revisions must also be arranged.

How will the curriculum guides be disseminated?

Introduction of a new curriculum guide to an entire staff of teachers can be a massive undertaking. Merely delivering the guides to teachers' mailboxes will not guarantee their implementation. An introduction planned around workshops or conferences would be more effective. At these meetings, the writing team can assist the supervisor in giving an overview of the guide to principals and teachers: this type of "walk through" provides an opportunity for the users to ask questions and work through the anxieties that changes engender.

Subsequent inservice workshops and demonstration lessons will assist teachers in using the guides and assessing student progress. Videotapes, hands-on activities, and other strategies must be developed for use in the inservice sessions.

Curriculum guide development is never really finished. Revisions and updates are always necessary and occur in an ongoing fashion. A formal revision is usually planned when reprinting is needed or at least every five years. A loose-leaf format allows the issuing of new pages in the interim. Inservice education needed for curriculum implementation is also an on-going process, requiring planning by the science supervisor.

Inservice Education

The relationship between curriculum development and inservice education, as previously discussed, determines one type of needed inservice. Science supervisors, however, are often expected to plan a diverse schedule of inservice opportunities to serve a variety of needs.

Any new project or program introduced to enrich the science program will likely require inservice training for the personnel involved. This includes specialized programs which are part of a federal or private grant received in response to a submitted proposal. In curriculum development projects and special programs, the need for inservice is relatively obvious. By periodically conducting a needs assessment, it is possible to identify other inservice opportunities that will help to fill specific needs of teachers. The teachers themselves usually know best what would be of value to them.

In most school districts a supervisor will find at least the following needs for both new and experienced teachers.

New Teachers

These staff members may either be new to the school system, or new to teaching, or both. In the first year they need information about the curriculum, the grading and promotion system, the maintenance of laboratories and supplies, and other system-related topics. Strategies for supporting these teachers include workshops, demonstration lessons, assigned mentors, and informative handbooks or procedural manuals. In subsequent years direct observations and follow-up conferences by the science supervisor help to establish the proficiency level reached by each new teacher. When the teacher has deficiencies, the supervisor can give advice to the rating officer and help to design a support plan for needed improvements. This plan may include suggestions for additional course work arranged through a local college or university, or attendance at special workshops sponsored by the school district.

Experienced Teachers

As teachers progress in their careers they need to be encouraged to remain aware of new findings in science, in educational research, and recent teaching strategies and techniques. An enterprising supervisor will consider ways to provide the opportunities for inservice that teachers request or may find of assistance.

Local college and university staff members are often interested in designing courses that answer the needs of teachers. The supervisor can be a facilitator in accomplishing this task by contributing advice on course content, special tuition arrangements, recertification credit requirements, and deciding the site for these courses.

Supervisors can also plan for internal inservice. Teachers can instruct each other in a workshop, or arrangements can be made for teachers to visit each other to make peer observations. With financial support, sought by the supervisor, a visiting speaker can be engaged to present a special topic.

Some districts have teacher incentive awards. The supervisor can assist teachers with writing proposals to obtain funds for special inservice opportunities. Local businesses or industries may lend speakers or staff members to the school district to assist teachers with specific curriculum topics. Teachers who need science experience find summer employment in local laboratories or doing field research through the efforts of the science supervisor. The supervisor who wishes to provide opportunities such as these must develop friendships and contacts among government, industrial, and educational leaders in the community and be ready to do the planning and arranging needed to set up these and other special kinds of educational opportunities.

Experienced teachers should be encouraged to participate in appropriate professional activities through membership in the National Science Teachers Association (NSTA), the National Science Supervisors Association (NSSA), National Biology Teachers Association (NABT), the National Earth Science Teachers Association (NESTA), and other such organizations. One way to develop interest in the work of these societies is to obtain funding for a group of teachers to attend a NSTA or NABT convention. After such an experience, many teachers feel more a part of the profession and begin a lifelong habit of attending and learning from educational conferences. This helps them to stay aware of current techniques, content, and teaching/learning strategies. Supervisors themselves need a constant stream of such experiences to assure their own professional growth.

Not nearly enough of what is known about how students learn is reflected in classroom practice. The supervisor should serve as a dissemination agent for research findings by publishing bulletins, newsletters, or abstracts of research, written in an accessible form so that busy teachers can digest the contents quickly. Special seminars can be devoted to exploring new findings in psychological, sociological, and other related research.

Teachers grow professionally when they are assisted by the science supervisor to write for professional publications. Successful teachers contribute to the profession when they share their ideas with each other. Supervisors also are in a position to encourage experienced teachers to work on professional society committees and to make presentations at conventions and conferences.

Teachers Who are Changing From One Discipline to Another

This is a special situation which requires carefully planned inservice topics. If teachers are involuntarily transferred into science from physical education, health, social studies, or some other area, then the first hurdle may be one of sparking enthusiasm for the new assignment. Workshop activities taken from the curriculum at appropriate levels may inspire their interest in science as they become absorbed in hands-on experiences. They may need a carefully guided "gripe" session or two as a way of expressing their anxieties. Supervisors may wish to provide a mentor or "buddy" to help such teachers become comfortable with the new content and procedures necessary in teaching a laboratory science.

Another group of teachers to be served are the increasing numbers of mid-life career change candidates. When science teachers are in demand, the gap is sometimes filled by relatively young military retirees or scientists and engineers who wish to undertake a new profession. Teachers with liberal arts degrees and proficiency in one or more of the sciences may have little or no pedagogical training. Special arrangements must be made for short-term inservice and additional professional course work so that these staff members can become skillful in classroom strategies without undue delay or financial hardship. Teacher training institutions are developing these special programs. In the meantime, the supervisor must find ways to provide close one-on-one support similar to that for first year teachers who have just graduated from a teacher preparation institution. The maturity of teachers in this mid-life category is often a valuable asset to the science program, so the special attention needed in these cases is a worthwhile investment of the science supervisor's time.

In summary, it can be said that an enlightened science supervisor makes a heavy investment when developing curriculum, keeping it updated, and putting it in the hands of creative teachers. These teachers educate students more effectively because of the inservice leadership provided by the science supervisor. The basic work of the science supervisor is in curriculum development and staff development. The curriculum materials may be based on the adoption of textbooks chosen for each course of grade level. A more useful form of curriculum may be one that is constructed goals and objectives agreed upon by the local community.

Inservice education opportunities are best planned by basing them on a needs assessment. New teachers, experienced teachers, and teachers who are changing fields need inservice especially planned for their individual concerns. Inservice is always necessary when a new curriculum or program is introduced. Although a science supervisor does many short-term exciting tasks, it is the work in curriculum and staff development that brings a feeling of long-term accomplishment and satisfaction to this very important staff position.

For over a decade, Mary Harbeck has served as a science supervisor of the District of Columbia Public Schools. Prior to that she taught science in both elementary and secondary schools in Pennsylvania, and was the Pennsylvania state science advisor for six years. Her publications include articles in professional journals, and she was the editor and author for the Second Sourcebook for Science Supervisors *(1976).*

The Science Supervisor's Role in Staff Development 12

RONALD E. CHARLTON
MT. LEBANON SCHOOL DISTRICT

In the continually changing world of science and science education, the science supervisor's primary responsibility is staff development. Staff development is essential for science teachers to maintain content knowledge and refine teaching techniques.

Content Updates

Many staff development activities can help keep science teachers aware of these new developments in content areas. One of the most useful activities to provide is a content update as part of an inservice day. Experts from a local university or industry can be brought to your school for very specific content updates. If the speaker cannot be there in person, a videotaped presentation can be a workable, if limiting, alternative. Such a substitute does not give teachers an opportunity to ask questions and get immediate answers, or give the expert a chance to tailor his or her presentation to the audience's reaction.

The update could be for the entire science department or for teachers of specific subjects. The science supervisor may determine the focus of the content update based upon his or her knowledge of the overall science curriculum. However, involving the science department staff in the selection process and letting them identify their needs and interests will make the update more meaningful and successful. Your teachers may even suggest specific individuals as presenters. It is best to tell the presenter exactly what is expected in the update session.

Depending on your particular situation, content updates may be given at the presenter's site. Many museums, science centers, and research laboratories will give update workshops at their facilities. This tyoe of update is most appropriate when the latest equipment and procedures must be used, or when materials cannot be easily transported to your school.

Content updates can also be conducted by teachers from your own staff. Although all of us involved with science education read about and study new scientific breakthroughs, no one has time to read enough. Your own teachers represent an excellent and, unfortunately, often untapped resource. This is especially true of teachers taking graduate courses or who have attended conferences, conventions, or summer institutes.

Secondary science teachers can be valuable resources for elementary teachers who may not have a strong background in science content and who have even less time to keep up with new developments. What may be a simple demonstration or easy activity could be just the spark needed to inspire an elementary teacher and his or her students.

Out-of-School Opportunities

A second type of staff development can be out-of-school participation in a wide range of science-related activities. Graduate courses in science and science education should improve the quality of one's science teaching. Many colleges and universities have continuing education programs tailored to the needs of science teachers. Equally valuable are the various summer institutes and workshops that focus on particular aspects of science education, such as teaching advanced placement courses, National Science Foundation honors workshops, and leadership projects. Professional organizations such as the National Association of Biology Teachers sponsor in-depth summer update workshops held over several days. Don't overlook the many excellent Curriculum Study Institutes held by the Association for Supervision and Curriculum Development. Although the ASCD institutes do not deal specifically with science education, they do focus on practical application of current educational topics such as learning and teaching styles, thinking skills, and instructional leadership, many of which are applicable in the science classroom.

Science supervisors must encourage their science teachers to become involved in these academic endeavors. Notify teachers of the opportunities, help them complete the necessary reference forms, write letters of recommendation, recognize their accomplishments and achievements when they participate, and set an example by participating in such courses or programs yourself. Science supervisors must seek out and fight for the necessary funds that will permit your science department staff to have these opportunities.

Some summer jobs provide staff development for science teachers. Teachers are sometimes able to work in science-related jobs during the summer, as park rangers or laboratory technicians, for example. Although science teachers often seek science-related summer employment independently, it is encouraging that throughout the country there appears to be a growing coalition among science educators and the business community to provide meaningful summer work experience for science teachers.

Membership in professional science or science education organizations is another excellent source of staff development. Every science teacher should be encouraged to belong to at least one. The journals of these organizations help science teachers stay in touch with current developments in their field. *The Science Teacher,* published by the National Science Teachers Association, has a good balance between science articles and science education articles, as well as news of the association. Belonging to professional organizations also gives science teachers a feeling of identity and companionship with others in the same profession. Through a professional organization, teachers can exchange ideas through the pages of a journal or in person at national and local conventions. The informal contacts and friendships may be the most valuable benefits of membership in professional organizations.

Broad-Based Programs

A third type of staff development involves science teachers in a school-wide or district-wide staff development program. In many cases these broad-based programs are not directly related to science, but focus on some aspect of education applicable to all content areas. The science supervisor should analyze the focus of these programs and help to put it into a meaningful framework for the science teachers. For example, if the staff development program focuses on thinking skills, the science supervisor must relate the examples and situations of a science class to the skills being covered in the general program.

The science supervisor must also clearly delineate the objectives of the staff development program and work with teachers to follow up on the ideas and techniques presented. After a program on teaching analysis, for example, a supervisor should assist teachers in developing lesson plans using skills of analysis, and observe the lesson as it is taught.

The science supervisor must insure that the science staff receives appropriate training, including learning how to explicitly teach skills, how to develop curriculum materials, and practicing the new teaching techniques several times before any evaluation occurs. As teachers begin to use new techniques, the science supervisor needs to be supportive and, at times, assume a coaching relationship with some teachers.

Broad-based staff development can sometimes be more meaningful if science teachers have an *esprit de corps,* if they have incentive to be the first department to complete a program, or the first to implement changes.

The "Buddy" System

A fourth type of staff development concerns new teachers. All of the variations of staff development discussed above apply to the new teacher as well as to the veteran, but the new teacher often needs some additional assistance to learn the system. One of your veteran master teachers could be asked to serve as a "buddy" for the newcomer. The veteran could help the new teacher learn to work with the bureaucracy of today's school as well as counsel him or her about curriculum, teaching methods, classroom management, and the many routine things that may be foreign to one just entering the profession.

The "buddy" also works well with a marginal teacher, regardless of experience. A fellow teacher is often better able to freely discuss a problem with a teacher having difficulties and to suggest methods of improvement. Use your master teachers as the valuable resources they indeed are.

Science supervisors have an obligation to help their science teachers become the best they can be. Effective staff development is one key to this. The science supervisor must be willing to plan, coordinate, seek funding, make recommendations, participate, and evaluate. The results—for teachers and for students—are worth it.

Ronald E. Charlton started his career as a seventh-grade science teacher in the Mt. Lebanon School District in 1967, where he is currently Supervisor-Secondary Education. His ongoing professional goal is the improvement of science education. He has written and spoken on the relationships between science education and topics such as futuristics, learning styles, thinking skills, and staff development.

What Should Science Supervisors Know About Laboratory or Classroom Facilities and Safety?

Suggestions for Constructing or Renovating Science Laboratory Facilities

13

RONALD E. CONVERSE
WILLIAM C. WRIGHT, AIA
CONROE INDEPENDENT SCHOOL DISTRICT

While science supervisors have little formal preparation in providing or updating science facilities, most will, at some point in their careers, be faced with such a task. The purpose of this article is to present some general information to help science supervisors who must construct or remodel science facilities. There is not room to cover all of the considerations necessary to carry out these functions; therefore, this article will focus on developing a list of resources, general vocabulary, and procedures which will ensure the maximum chance of success.

Who Should Be Involved

In larger districts, an architect or similar coordinating individual will often be responsible for the planning and construction of facilities. In smaller districts, an architect in the community is often hired as a consultant. The architect advises on the cost of a renovation project or new construction. This person is usually well versed in the bidding process.

If an architect from outside the district needs to be hired, the selection process may involve action by the Board of Education. The interviews, reference checks, project visits, and final selection can take six to eight weeks or longer.

The building principal and teachers must take part in planning. The principal can advise in matters such as room capacity and anticipated growth of the school. Teachers are the ones who will be using the facilities: their input is essential for the development of facilities that will have maximum benefit for the type of program involved. At the same time, it is important to remember that, while teachers and administrators change periodically, the facilities will be permanent. In planning new construction, staff from similar school(s) can substitute for teachers not yet assigned.

The science supervisor, architect, principal, and teachers form the nucleus of a planning committee. This group should have time allocated for meeting. It is also desirable that funds be provided for substitute teachers and travel to allow the planning committee to visit facilities both in and out of the district.

Developing a Needs Statement

The first function of the planning committee is to establish a needs statement. This statement should include the reasons for renovating or constructing facilities. It should also include the number of rooms needed, the classes they will serve, and the number of students for each class.

The needs statement serves as a basis for obtaining tentative district approval to proceed with the planning. Obtaining this approval may involve the assistant superintendent for instruction, the assistant superintendent for finances, and the superintendent; in some cases, an informational presentation to the Board of Education may also be required. It is important to obtain this tentative approval since there is little reason to proceed if the project is not of high priority to the district.

Allocating Time

Planning for science facilities can take much of a supervisor's time and energy since few shortcuts can be taken; the facilities, once completed, will be used for many years. Teachers and students using these facilities will suffer if planning and construction are rushed.

The first priority is planning a time line for the project. Start at the date the facilities will be needed and work backward. Below are questions which need to be answered to establish a time line:

1. When will the facilities be needed?

2. How much time is necessary for stocking the rooms? (This includes unpacking or moving materials for use in the rooms, stocking shelves and drawers, etc. If these materials, supplies, and equipment are new, ordering should take place early so they are available when needed.)

3. How much time will be required for testing or inspecting plumbing, gas, and electricity prior to approving the rooms for use? Inspection is done by city inspectors who will confirm the findings of the architect and engineers. The city then issues an occupancy certificate.

4. How much time will be required for the final hookups of water, gas, and electricity once the furniture is installed?

5. How much time will be required for installing the laboratory furnishings once they are delivered?

6. How many days will be required to prepare the rooms for installation?

7. How much time will be required for a vendor to deliver the furnishings once the order is placed?

8. How much time will be required to prepare and transmit a purchase order once the purchase is approved?

9. How much time will be necessary to analyze and make recommendations once a bid is received so the item can be placed on the Board of Education agenda? (Remember: In most school districts, the Board meets only once a month. At least a full month will be lost if you miss being placed on the agenda.)

10. How many days minimum must elapse between the advertisement of a project and the bid date?

11. How many days minimum must a bid be legally advertised?

12. How many days will be required to prepare the bid specification documents and have them printed?

After answering these questions, the date by which all planning must be completed can be determined. The planning time depends on the size and complexity of the project. If extensive renovation is to be done, a general contractor, rather than district construction crews, is likely to be involved. Question 6 may then become very complicated. Additional bid specifications will be needed for the preparation of the facilities. Here the architect and his engineering consultant must design, draw, and specify all rough-in connections for water, gas, and electricity, plus any changes or additions to the lighting or room ventilation, to satisfy the science program's needs.

Finding Information

Numerous sources of information on science facilities are available. Publications of the National Science Teachers Association, such as *Conditions for Good Science Teaching* (Showalter, 1984), are helpful. Some states prepare a guide for planning facilities. For instance, the Texas Education Agency (TEA) publishes their guidelines, *Planning a Safe and Effective Learning Environment for Science* (TEA, 1980); other professional organizations such as the American Chemical Society often publish articles on facilities. Sometimes information is found in unlikely sources, such as an excellent article in *American School and University* (Hill, 1985). It is wise for a science supervisor to routinely copy and file articles on facilities for later use.

School districts that have changed existing facilities or constructed new ones are another source of information. Contact your local or state science supervisors association and request information on districts which have exemplary facilities or have recently constructed facilities. The experiences of others can be a source of inspiration. For example, Richardson Independent School District in Texas solved storage problems with rolling storage units that fit into a compact space without aisles. The units are rolled out when needed. The Shawnee Mission Public School District in Kansas installed a separate exhaust system at every student station in their five high schools' chemistry laboratories; Conroe Independent School District in Texas installed four elementary science resource centers patterned after NSTA's Anne Beers project (Harbeck, 1985). The Kalamazoo Public Schools in Michigan recently renovated an old high school to provide facilities for a science and mathematics magnet school. The science supervisors in these districts and in others can offer information on how they solved unique problems.

Vendors of science furnishings can also provide information. A list of several companies who sell laboratory furnishings is given at the end of this article. Vendors can provide names of districts who have recently purchased their products. They will also be more than happy to provide drawings of suggested room designs for the planning committee.

When working with vendors, it is a good idea to give them blueprints of existing facilities. Be sure to provide not only a copy of blueprints showing the room locations and dimensions, but also sheets showing plumbing and electrical layouts. A meeting between vendors and the planning committee will also aid the vendors in providing plans acceptable to the committee.

Use, Size, and Capacities

The planning committee must first consider what courses will be taught in each room. Rooms should be designed for a specific course while being as utilitarian as possible.

Secondly, it must be decided if the room will be used only for laboratory activities, or for both laboratory and classroom activities. The room's use effectively determines its size. NSTA's recommendations (Showalter, 1984) that laboratory activities should comprise at least 40 percent and no more 80 percent of instructional time seem to dictate a combination laboratory/classroom design. If science classrooms do not provide for both laboratory and classroom activities, scheduling laboratory rooms becomes an additional task. It is also difficult for laboratory activities requiring observations over an extended period of time to be carried out when two teachers share a laboratory.

The combination laboratory/classroom is supported by sources other than NSTA. The room design chosen by the Orange County Public Schools in Florida after extensive research was a combination laboratory/classroom design (Hill, 1985). Recommendations for Texas schools state that classrooms must facilitate a laboratory approach to instruction, and suggest combination laboratory/classroom designs for new construction (TEA, 1980). This design also has the advantage of permitting a class period to be divided into laboratory and recitation segments.

A third factor which must be determined before choosing the room design for secondary schools is room size. Showalter (1984) indicates that a minimum of 5.5 square meters (59.2 square feet) should be allotted per student in combination classrooms and 4 square meters (43 square feet) should be allotted per student in space used strictly for laboratory. The TEA (1980) suggests 45 square feet per student plus an additional 15 square feet per student for storage and preparation in combination classrooms. Young (1972), writing specifically of laboratory space, found that the accident potential for a class increases when the square feet per student falls below 41. The accident potential remained fairly constant when the square feet per student was above 41.

A fourth factor which must be considered is the maximum number of students who will use the facilities. Showalter (1984) indicates that there should be no more than 24 students per class in grades K–12. TEA (1980) recommends 24 students per class, with enrollment never exceeding 30. Florida state statute limits the class size to 24 students (Hill, 1985). Young (1972) reported that the percentage of total accident encounters rises when an increase occurs in class size. Young determined a reasonable and safe class size was 22 students.

Possible Designs

Following are four examples of some of the more common laboratory designs used in schools for science instruction. Many potential designs are available that should be explored with vendors and the planning committee.

The combination laboratory/classroom using a peripheral laboratory design is popular (Figure 1). This design provides excellent visibility for the instructor, good traffic patterns, and easy evacuation. It also requires only one floor or wall penetration for services. The services are then run around the room next to the wall in a chase, normally six inches wide, behind the base cabinets (Figure 2). Individual student storage is provided under the work areas. More storage is provided around two sides of the room in lower and upper cabinets. With minor variations, the design can serve for any course traditionally offered in the high school. In schools using this design, students are sometimes provided stools to use when working with microscopes at standing height work spaces.

Biology does not use gas and, to some extent, water as frequently as chemistry or physical science. While the peripheral design works well for biology, another design suitable for biology is shown in Figure 3. This design, while not as utilitarian as the peripheral design, is less expensive to construct. Electricity is provided by mounting heavy-duty electrical cord reels on the ceiling above the tables. Students in biology can easily do microscope and dissection activities at the tables. When gas or water is required, students can access these services at the side counters.

An island design is shown in Figure 4. These islands can contain storage for student materials. This design is often advantageous when facilities cannot be located next to walls because of the presence of low windows.

Another common arrangement could be called a row design. This design is similar to the island design. It differs primarily in the fact that the row design requires fewer floor penetrations for services. It does reduce the teacher's view of students, and the teacher must walk a greater distance when helping students at lab stations. Two variations of the row design are shown in Figure 5.

Safety Considerations

Safety must be the primary concern when constructing or renovating rooms for laboratory use. Space does not permit a lengthy treatment of this topic. Current information on safety equipment and procedures must be consulted and considered when designing facilities. Rooms should have more than one exit so that if one door is blocked, evacuation is still possible. Central shutoff should be provided for electricity, gas, and water. Drenchers and/or eye wash stations should be provided in every room. A safety shower and fume hood should be available in every chemistry and physical science room. Remember, fume hoods are not suitable for room ventilation. Room ventilation is a separate consideration.

All cabinets and drawers in the room should be provided with locks. Locks are expensive and often omitted from specifications. Their absence renders much of the storage in the classroom useless, since safety procedures require that most laboratory materials and equipment be in locked cabinets or drawers. All locks should be keyed both individually and to a room master. If a large number of rooms are involved, locks should also be keyed to both a room and a single department master key. If keyed in this manner, the science department chairperson, custodian, and building administration will only require one key.

Any plate glass in the laboratory areas must be safety or tempered glass. This includes display cases as well as fume hood doors. Storage cabinets in the classroom should not have glass fronts.

Preparation Rooms

Preparation rooms should provide an adequate area for preparing materials for laboratory use as well as for cleaning up after the laboratory activity. A large sink with hot and cold water should be provided. When possible, a fume hood should be available in chemistry preparation rooms. This can often be accomplished by installing a fume hood in a common wall between the preparation room and laboratory room. A hood with doors on both sides can thus serve a dual purpose. The fume hood door on the preparation room side should have a barrel lock installed so it can be locked in the

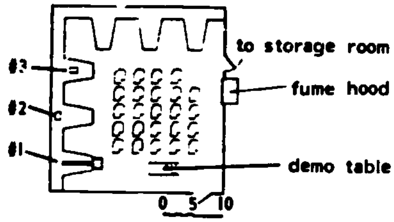


Figure #1 PERIPHERAL LABORATORY

Optional Sink Locations:
#1 Chemistry; tub sink with optional trough in countertop
#2 Physics or Biology
#3 Physical Science

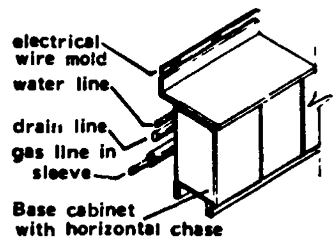


Figure #2 BASE CABINET SHOWING CHASE

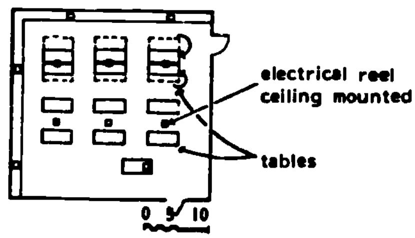


Figure #3 TYPICAL BIOLOGY LABORATORY/CLASSROOM

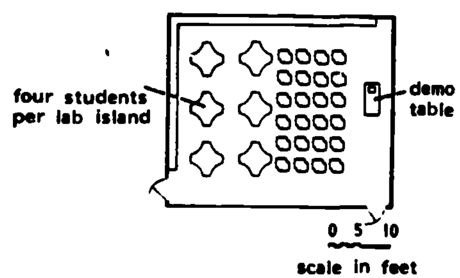


Figure #4 ISLAND DESIGN

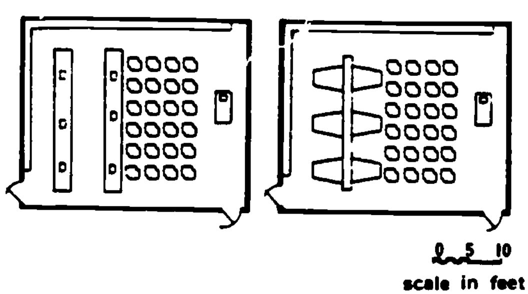


Figure #5 ROW DESIGNS

down position.

Shelving for chemical storage should be fixed and have a lip on the front edge. Since preparation rooms are secure, open shelving is normally used. Space should be provided in the preparation room for flammable and corrosive material.

Consideration should be given to space for special equipment. In biology rooms, space should be allowed for a refrigerator. In rooms for biology, chemistry, and perhaps physical science, a laboratory-grade dishwasher may be desirable.

Services

All secondary laboratory rooms should have cold water, gas, and electricity. Hot water should be provided at all demonstration tables and in the preparation rooms. All rooms should be provided with 3.75-centimeter (1.5-inch) acid waste lines. The architect is familiar with local construction codes and will be able to specify the type of materials used to conduct services and waste lines. He or she can also determine if an acid dilution basin is already in place or will need to be provided.

Materials

Materials used in the laboratory furnishings are most important. Cost-cutting in this area can result in a laboratory that must be renovated in a very short time. Plastic laminates are quite acceptable for elementary facilities. Where these laminates are likely to be in contact with water, a wood core (not particle board) should be specified. At the middle school level, laminates are also acceptable, especially in preparation areas and classrooms for life and earth science. Serious consideration should be given to wood cabinets for general science classes.

In the high school laboratory, wood cabinets are most appropriate, although they are also considerably more expensive than other materials. If cost becomes a critical factor, laminates might be used in areas of the physical science, biology, and physics rooms, but they do not hold up well in chemistry rooms.

A major part of the expense of laboratory facilities is the material used for countertops and work surfaces. Materials for these surfaces include natural stone and epoxy resin. Careful consideration must be given to this area. Most vendors will provide detailed specifications on their top materials and recommend which material should be used. It is important that specifications be written in such a way that all bidders will be providing materials with similar characteristics.

Renovating or constructing laboratory facilities is a complicated and time-consuming task. An adequate budget must be provided to prepare or construct the rooms as well as purchase and install the furnishings. Money must also be budgeted to provide the materials, equipment, and supplies necessary to use the room for its intended purpose.

The science supervisor must rely on the architect and representatives of the laboratory furniture industry. By working with these specialists to meet the desires of the building representatives on the planning committee, a standardized and cost-effective product can be specified. The preparation of comprehensive competitive specifications upon which all responsible vendors can bid will result in the highest quality materials and services at the lowest cost.

A science supervisor who has gone through all that is involved in justifying the need for new or renovated facilities and succeeded in obtaining the facilities has a very special feeling when visiting a class and watching the students use the facilities. Those students and all other students who will benefit from the laboratory facilities in following years make all the work required worthwhile.

References

Harbeck, Mary B. (1985). Getting the most out of elementary science. *Science and Children, 23*(2), 44–45.

Hill, Franklin. (1985). A master plan for science. *American School and University, 57*(10), 62–66.

Showalter, Victor M. (Ed.). (1984). *Conditions for good science teaching*. Washington, DC: National Science Teachers Association.

Texas Education Agency. (1980). *Planning a safe and effective learning environment for science*. Austin, TX: Author.

Young, John R. (1972). A second survey of safety in Illinois high school laboratories. *Journal of Chemical Education, 49*, 55.

Ron Converse has classroom experience ranging from grade 3 through teaching chemistry at the university level. He has been involved in or responsible for the construction or renovation of science facilities in two major school districts. He was a teacher and administrator with the Shaunee Mission Public Schools for 20 years; for the last 4 years has been the K–12 science coordinator with the Conroe Independent School District.

Bill Wright, AIA, is the director of planning and construction for Conroe Independent School District. His training includes a business degree from the Univerisity of North Dakota and an architecture degree from the University of California at Berkeley. He has supervised school construction projects totalling $50 million in the last 8 years.

Representative List of Vendors

The following list of vendors is not exhaustive. The vendors listed are national and have representatives in all states. They also provide a complete line of laboratory furnishings. There are many other national and regional vendors. Science supervisors should obtain a list of vendors who have good reputations from their state supervisor or the state education agency.

American Hamilton: 1316 18th Street; Two Rivers, WI 54214, (414) 793-1121.

Kewaunee Scientific Equipment Corporation: P.O. Box 5400, Statesville, NC 28677, (704) 873-7202.

Sheldon Division, General Equipment Manufacturers: P.O. Box 836, Crystal Springs, MS 39059, (601) 892-2731.

Taylor Division, American Desk: Box 1069, 1353 West 2nd St., Taylor, TX 76574, (512) 352-6371.

Planning of Facilities for Teaching Science in Elementary and Secondary Schools

14

PAUL H. TAYLOR
NORTH CAROLINA DEPARTMENT OF PUBLIC INSTRUCTION

Winston Churchill once said, "We shape our facilities; thereafter, they shape us." A well-designed facility can supplement a well-planned program. On the other hand, a poorly-designed facility can hamper a well-planned program. Indeed, Engelhardt (1968) found that architecture is one of several significant influences on teaching methods used in science instruction.

The facility most likely to be functional and supportive of a science program is one which is designed around student, teacher, and program needs. Program planning should always precede facility planning.

Science instruction at all levels must take into consideration individual differences in interests, abilities, and modes of learning. Likewise, individual differences must also be recognized by facility planners. Much has been learned about the methods and conditions under which students learn best. Many leaders in the field of science education, and in the field of education in general, feel that there should be less lecturing and demonstrating to students at the secondary school level and more individual and group experiments and activities, with the teacher serving as a consultant. While the responsibility for creating and maintaining an intellectual atmosphere conducive to teaching and learning belongs to the teacher, the physical facilities play an equally important role.

Whether the science facility being planned is a part of an entirely new school, or an addition or renovation to an existing building, certain steps can be taken to accomplish the task successfully. Educators approach the job in a variety of ways.

Educational Specifications

Educational specifications can be considered a general statement of the problem to be solved by the design professionals (National Council on Schoolhouse Construction, 1964). Specifications are normally prepared by a committee appointed by a local superintendent and composed of central office staff, principals, teachers, students, parents, and citizens representing various community groups. The composition of such a committee may vary depending upon the size and complexity of the facility to

... of this chapter originally appeared in *The Science Teacher*, March 1980.

be designed and built. The main purpose for developing educational specifications is to provide an effective means of communication between the local administrative unit and the design professionals (architects, landscape architects, and engineers). The specifications should describe in detail the activities that are proposed for the facility. In essence, the committee's responsibility is to provide a description of the facility needs for implementing a well-planned science program. The responsibility of the design professionals, in turn, is to design facilities to accommodate these needs.

Educational specifications should be written as concisely as possible. To ensure conciseness, the committee should adopt a format for the educational specifications. A brief discussion of suggested format items follows.

Educational Philosophy

The educational philosophy can provide direction in all subsequent planning of programs and facilities and serve as a benchmark against which facilities and the program can later be evaluated. The philosophy may be in narrative form or in the form of a simple list of basic beliefs. In any event, it should be stated simply and concisely.

Objectives of Science Teaching

The desired outcomes in relation to student performance should be stated or listed in this section. Some may wish to list performance objectives for each subject area. The more current approach, however, is to think of the major objectives of science teaching as essentially the same for science at any level or in any specific subject area.

Identifying Trends

Major trends in the area of science instruction should be identified by the committee. The trends and their implications for the science program and the facility should be written as thoroughly yet concisely as possible.

Teaching Methods

Before describing methods to be used in a new facility, the committee should review the teaching methods presently being used. The methods the committee thinks will best accomplish the philosophy and objectives of the planned program should be carefully considered. This component of the educational specifications is a most critical one: Unless it is done thoroughly, facilities may later determine the teaching methodology used.

Activities

Activities that will take place in the instructional and auxiliary areas should be listed or described. The number of persons (groups, individuals) to be involved in the various activities should be given. Knowing as much as possible about the activities to occur in each of the different areas will aid the architect in designing for sound and visual considerations. The mechanical/electrical support systems—cooling, heating, lighting, exhausting—will most likely be affected by the nature of the activities that will take place in the different areas. The activities, to a great extent, will determine the type of spaces, furniture, and equipment needed to support the science program.

General Information

This is the place to list the grade levels, the maximum projected science enrollment, and the maximum class size to be accommodated by the new facility. The daily time schedule—number of class periods, modules, rotating schedule—should be described. Courses and number of classes per period of time (day, week) at the secondary level need to be stated. From the above information, the types and number of spaces (e.g., classroom-laboratories, multipurpose rooms, student project rooms, teacher offices) needed can be calculated and listed. If the structure is being planned for elementary school science, it will in most cases be a multipurpose room for different subjects. To assist the architect in allocating space in the plans for the entire science program, projected space requirements for each of the instructional and auxiliary spaces should be provided. If additional facilities (e.g., greenhouse, planetarium) are planned for the future, they should be listed here so that their projected locations can be integrated into the overall design.

Specification for Main Instructional and Auxiliary Areas

List and describe in detail what is desired and needed in the way of instructional and support areas, classroom and laboratory furniture, and utilities. Furniture, by type, size, quantity, and location should be listed and described. The committee should visit several schools with well-designed facilities to help them in preparing this most important section of the educational specifications.

Any special environmental considerations such as special visual, acoustical, or mechanical requirements should be made known at this point. Examples of such considerations are light control and soundproof capabilities, a special exhaust system in chemistry areas, and acoustical privacy in reading/study areas.

Requirements for special facilities, equipment, and systems such as closed-circuit television, information retrieval systems, computers, and specially equipped carrels should be listed and described. It is easier and cheaper to design and install utilities for these items in the beginning than to do so later.

The size and shape of needed storage facilities should be described here. Architects need to know which areas will be open or enclosed, which areas require security provisions, and which areas should be designed for the storage of hazardous and/or corrosive chemicals. Separate storage facilities for sensitive equipment—especially delicate metal items—should be specified.

If the committee thinks it is important for the science complex to be either separate from or adjacent to other discipline or special service support areas, such specifications should be indicated. It has been found that if science students have to walk past only science classes on their way to the library, library use increases (Engelhardt, 1970).

To ensure better communication between the specifications committee and the architect, the committee may construct graphic or pictorial representations of layout concepts and/or spatial relationships.

Miscellaneous Information

This is the place to describe information not appropriate in any of the above sections. If the committee finds no need for such a section, however, it may be omitted.

Once the committee has finished developing the educational specifications, its major input into the planning and designing of the science facility is near completion; however, it should remain available to confer with the architect and engineer throughout the development of the schematics and working drawings. The specifications should then be typed or printed in a format convenient to follow and be presented to the local board of education.

Factors to Consider When Planning Science Facilities

The physical aspects of a science facility—its components, dimensions, and design—can enhance or inhibit what is to be learned and affect the feasibility of using certain instructional strategies. Thus, it is important for facility planners to understand the relationship between facility design and the nature of learning. It is also important that they know what characteristics and components of a science facility are needed in order to provide the most effective support for a well-planned science program.

Following are factors to consider when designing and planning school science facilities. They should be of particular interest and help to those persons with little relevant experience who find themselves involved in developing educational specifications for new science facilities:

- Using ideas from many sources in planning science facilities
- Budget for equipment and materials
- Site selection

- General characteristics of science rooms
- Recognition of individual differences
- The visual, acoustical, and thermal environments
- Ventilation
- Safety
- Space requirements
- Rooms and spaces
- Spatial relationships
- Clustering
- Chalkboards
- Facilities for handicapped students
- Provisions for media usage
- Computers
- Factors related to science classroom furniture

Using Ideas From Many Sources in Planning Science Facilities

It is important to seek ideas from many sources when planning science facilities. Science teachers' ideas should certainly be solicited. Persons responsible for preparing science teachers should be consulted, as well as the people closely concerned with the operation of schools—board members, school administrators, school plant operators.

The ideas of planning experts may be obtained through published articles and books. Local persons—business personnel, druggists, scientists, naturalists—may have ideas worth considering. The ideas of students and recent alumni should not be overlooked. While students may not be able to offer many worthwhile ideas, their involvement in the planning process will probably result in more positive attitudes toward the science program and the new facilities.

Budget for Equipment and Materials

All too frequently, science facilities are planned and built with insufficient consideration given to providing the funds needed to purchase tools of instruction—equipment and materials—the "nuts and bolts" of science instruction. This oversight often presents the instructional staff with a situation that makes it impossible to carry out a well-planned laboratory-oriented program. To omit such items from the overall plan is like failing to provide electrical appliances and cooking utensils for home economics, or typewriters for the typing class.

Normally, equipment and materials are not included in the general construction contract. Therefore, a budget for equipment and materials should be made at the same time that one for the general contract is being prepared.

Site Selection

When a site for a new school is selected, consideration should be given to the potential contributions of the site to the teaching of science. Preservation of natural features on a school site can make science instruction much more meaningful than it is in the classrooms alone. Natural areas can be used especially well with biological and earth science classes. Portions of the site should be staked off to prevent damage to their naturalness during construction of the school.

Not only can natural areas on a school site be incorporated into the educational process, they can, if properly maintained, also enhance the school's aesthetics. The services of a landscape architect may be required.

General Characteristics of Science Rooms

In this section, "science room" refers to the main instructional area, whether it be a multipurpose room, a classroom-laboratory combination, a specialized laboratory, or a student project-laboratory. *For the rooms to be appropriately designed and located, the science program must be planned first.* The general nature of science demands facilities which will permit many types of activities and the use of equipment and materials under a variety of classroom organizations. The rooms should be flexible enough to allow for entire class, small group, or individual activities, especially if they are being designed for elementary school science.

Recognition of Individual Differences

Individual differences among students call for facilities that can be altered or rearranged. Science rooms, especially in small schools, should be so arranged and furnished that they can be used for different science courses and for a wide variety of activities within each course. Such rooms make possible the use of many teaching methods and techniques which can effectively accommodate the individual differences among students.

Environmental Considerations

Human beings are both consciously and subconsciously affected by their environments: The physiological and psychological effects of the environment in terms of heat, light, sound, and space have been researched and documented to some extent. However, research has been less successful in supplying answers about the effects of the environment on human attitudes and behavior. Although architects and interior designers try to take into consideration the effects of the environment upon humans, their work is usually based largely on personal preference, imagination, and intuition rather than on the results of systematic research. As more is learned about environmental psychology, responsible planners should keep abreast of the new information and its implications for educational facilities (Council for Educational Facility Planners, 1976).

The Visual Learning Environment

It is generally agreed that most learning comes about through the sense of vision (McVey, 1971). Conditions allowing fast, accurate, and comfortable visibility must be provided in educational facilities. The level of illumination is not the only factor to be considered: balanced brightness and the elimination of glare also contribute to visual accuracy and comfort.

Planning and designing an efficient visual learning environment for a science facility is a job for professionals—architects, as well as visual and illumination engineers. Educators can assist with the task by defining the program to be offered, identifying the users, and describing desired physical features.

The Acoustical Learning Environment

Designing a good acoustical environment in an educational facility involves solving two problems: controlling the sound within a particular space, and preventing the intrusion of unwanted sounds from outside the space (Council for Educational Facility Planners, 1976).

The objective in acoustical design should be to secure desired speaking and hearing conditions in an aesthetically pleasing setting at the lowest possible cost. Traditionally, acoustical considerations have been focused on specialized spaces such as auditoriums, libraries, and broadcasting and recording studios. However, the need for controlling noise in regular study areas and laboratories is now widely recognized. A quiet environment results in greater efficiency and alertness. It is generally credited with decreasing fatigue and mental strain. Consequently, acoustical treatment must be a prime consideration in the design of all educational facilities.

The Thermal Learning Environment

Until recent years, the thermal environment in elementary and secondary schools was equated with heating and was considered relatively unimportant in planning new facilities. Even today, too many school planners—educators, architects, engineers—still fail to realize or understand the impact of the thermal environment upon teacher effectiveness and student performance. However, the situation continues to improve as more is learned about desirable thermal environments and their effects on students and teachers.

Business and industry leaders have long been sensitive to the belief that improvement of thermal environmental conditions increases the productivity of their workers. Evidence from subjective observations suggests that students enjoy more and perform better in schools with a well-designed thermal setting. A study by the University of Iowa revealed the following:

Preliminary research by the Iowa Center reveals that there is significant positive relationship between the thermal environment in which children work and study and their efficiency in learning. Children did learn better under model thermal conditions. The knowledge of this relationship affords an increased control over mental functions in the classroom. It adds to our understanding, gives us power to increase efficiency in learning, and places on us the responsibility to provide the favorable environment for learning. (Peccolo, 1963)

Human beings are complex organisms that do not function well at high or low temperatures. Student efficiency declines when temperature of the air and surrounding surfaces vary much from an optimum temperature of 21 to 24 degrees Celsius (70 to 75 degrees Fahrenheit). Due to such differences as dress, metabolic rate, and reactions of individuals to heat and cold, opinions vary among classroom occupants concerning a desirable temperature. Women generally prefer a temperature about two degrees above that preferred by men. Students, in general, prefer a lower temperature than do adults (Gilliland, 1969).

Current circumstances influencing the design of heating, ventilating, and air conditioning systems for schools today include: (1) the "open-school" plan, (2) the cost of energy and the need for energy conservation, (3) extended community use of the school and year-round schooling, and (4) the pressure for economy. The flexibility built into today's educational facilities has dramatically increased problems of heating and cooling. These problems have been compounded by the increased use of electronic media and variety in the shapes and sizes of learning spaces (Council of Educational Facility Planners, International, 1976).

These three aspects of the learning environment—visual, acoustical, and thermal—are all important to the safety, comfort, and well-being of the users of science facilities. They are interrelated. For example, the heat load of the lighting system must be entered into the calculations for the thermal environment; likewise, the noise factor of the thermal systems must be taken into consideration in the design of the acoustical environment. Acoustical treatment (e.g., carpet) in some cases can enhance the thermal environment and vice versa. Fluorescent lighting contributes to the background noise level of the classroom and ballasts should be selected with this in mind. All of these interrelationships point to the necessity for coordination in the designing of the different environments of an educational facility. Well-designed environments can be accomplished only through cooperative efforts of educators, architects, engineers, and specialized consultants. Architects normally assume the leading role in coordinating the efforts of the different groups.

Ventilation

The ventilation and exhaust facilities for the science complex should be adequate and independent of all others. The ventilation system should move odors from the science area directly to the exterior to avoid their penetration of other parts of the building. Care should be taken, though, not to vent the fumes outside near air intakes. Ducts carrying fumes, especially those leading from chemistry and chemical storage areas, should be made of (or lined with) noncorrodible material.

Planning for adequate ventilation is a most critical phase of the entire facility planning process. Proper ventilation not only provides for the comfort and safety of the users of the science areas, it also helps prevent equipment and material deterioration and makes for easier maintenance. The responsibility for designing an appropriate ventilation system is that of the architect and engineer. The job of the educators is to inform the architect and engineer as to what the science program is going to be and how the area is going to be used. The educators should be as specific as possible regarding activities to be conducted, equipment and materials to be used, and the nature of substances to be stored in the various areas. The technical aspects of the job and the code specifications should be left to the architect and engineer.

Safety

Prominent in the minds of facility planners should be concern for the safety of those who will be using the facilities. Due to the general nature of science, science laboratories are among the most hazardous instructional areas in the school. Attention should be given not only to the design of facilities that promote safety, but to the establishment of emergency procedures.

The variety of laboratory activities necessitates special planning, particularly with regard to fire and accident prevention and for first aid. Provisions for good housekeeping and storage contribute to both safety and cleanliness. The basic design and arrangement of the room furnishings and the nature of the interior construction should be planned for comfort, safety, health, and ease of maintenance (Richardson, 1961).

Space Requirements

The study of science requires much classroom, storage, and auxiliary space. Attention should be given both to the allocation and distribution of space. The amount of space to be allocated to the science complex within a school is determined by the type of program offered and the number of students served. The ability to rearrange space to accommodate small group or individual project work should be considered: without this capacity, some valuable learning activities may be sacrificed.

Rooms and Spaces

With the recent innovations in individualized instruction, expanded curricula, and flexible scheduling, special attention should be given to the design of rooms and other spaces which support the science program. The National Science Teachers Association states the importance of carefully designed rooms and spaces for science instruction:

Certainly there is some element of truth in the romantic notion that learning can take place anywhere and under any circumstances. But the larger truth is that the systematic, effective learning of science by large numbers of students requires the provision of rooms and spaces carefully designed for that purpose. These learning spaces and their furnishings must take into account: (a) the great diversity of students who will use them, (b) the nature of science, (c) current approaches to and trends in science teaching, and (d) the need always to keep the safety of students foremost in mind. The consequence will be a set of well-furnished and safe science rooms that include spaces for laboratory work, for group instruction, and for individual study. (1970)

If a sufficient number of well-designed rooms and spaces are to be included in the new school, the educators must provide the design professionals with appropriate information. Again, before this information can be provided, the science program must be thoroughly planned and the need for a variety of spaces carefully considered.

Spatial Relationships

Facility planners should carefully consid the location of the science complex in relation to other areas of the school. Details of the desired relationships should be included in the educational specifications. Specifications for spatial relationships should be prepared by an interdisciplinary group, including representation from all disciplines, the media center, the guidance department, and the administration.

Clustering

There are advantages to clustering all the indoor science rooms and spaces in one general area. One important consideration is cost: Less footage of drainage, water, and gas lines is required when the science complex takes the clustered form. The separate ventilating and air conditioning systems are less costly and probably less complicated to design, and multi-use of equipment and materials is more likely to occur, reducing the necessity for duplication, especially of the more expensive, sophisticated pieces of equipment. In a large school, grouping the physical sciences together and the life sciences together within the cluster of science rooms could prove to be beneficial with regard to equipment usage and storage.

With the science facilities clustered, there is less likelihood that obnoxious odors will be spread from the science rooms throughout the rest of the building. Sometimes laboratory classes tend to be a little noisier than some other academic classes. Concentrating the "lab noises" may be desirable, especially for students and teachers in other subject areas.

Chalkboards

The chalkboard is still considered by many teachers from all disciplines to be an essential teaching tool. Once chalkboards are installed, they become permanent fixtures. For that reason, the selection of boards should be done very carefully.

From personal experience, observation, and advice from professionals in education, this writer recommends the slate (dark gray) chalkboard, especially for use in traditional classrooms. Slate is easily maintained; it may be cleaned and used immediately several times during a single class period, a characteristic desirable in connection with some science courses, especially the physical sciences. Where large, open spaces are used for instructional areas, planners may want to consider portable chalkboards or another material, since slate is rather heavy.

Contrary to what some believe, slate is available in sufficient quantities to satisfy a greater demand than that which exists today, according to James F. Wilson, assistant general manager, Natural Slate Blackboard Company, Pen Argyl, Pennsylvania. There are several active slate quarries in Pennsylvania. Natural slate is also quarried in Italy and exported to the United States. Consulting the custodian who is responsible for keeping the boards clean might also be worthwhile.

Facilities for Handicapped Students

Special consideration must be given to handicapped students when designing any educational facility. Differences between special education programs and regular education programs do not appear as definitive as they once did. Efforts to improve special programs for students with more conspicuous differences have highlighted differences that exist among all students. The lessening of the distinctions between special and non-special education and the recognition that all students are, in their own ways, different, have helped pave the way for the introduction of handicapped students into the mainstream of education. The rights of young people to equal treatment, equal education, and equal opportunity have been upheld by the courts. Educators and design professionals cannot afford to ignore trends in special education and its relationship to regular education. All students must be permitted to enter the mainstream of education.

Provisions for Media Usage

The frequency with which instructional media are used in any program will depend upon the accessibility and availability of both materials and equipment. Because of the problems involved in moving students from one area to another, audiovisual materials and equipment are used satisfactorily and effectively in the regular classroom. This preference for such media in the regular instructional setting has implications for the planning and designing of science classrooms. Attention must be given to adequate provisions for media usage in conjunction with the designing of the learning environments—visual, acoustical, thermal. Proper design of walls, floors, and ceiling surfaces for these environments may enhance or restrict the use of instructional media.

With the expanding variety of instructional media being developed, facilities must be planned with possible future developments in mind. Facility planners should think ahead many years to the possible electrical and communications requirements. Accessibility to raceways and conduits, as well as adaptability of the entire wiring system to future changes, should be given consideration.

Computers

Prior to the 1980s, computer-assisted instruction was used in only a small percentage of the science classes in this country, due in part to the costs, the sophisticated nature of computers, and preference for the active laboratory phase of viable science learning.

When computers were first introduced into the elementary and secondary schools, mathematics teachers were more likely than science teachers to request computer facilities and to provide instruction in their use. However, this is no longer the case. Many science teachers are now using computers with their students to solve a variety of laboratory problems. Since both science and mathematics students are increasing their use of computers, educators might do well to keep this in mind and plan computer facilities which are convenient for both mathematics and science classes.

Educators and architects should call upon professional consultants for advice in planning and designing space for computer facilities. Computer technology is advancing so rapidly that special consideration may need to be given to designing for future advancements.

Factors Related to Science Classroom Furniture

It is important to provide furniture which is aesthetically pleasing and physically comfortable. It is also important to select furniture which is durable. Below are some important aspects of science furniture for secondary schools which should be taken into consideration when furniture selections are being made.

1. Stand-up work counters are normally about 90 cm (36") high.

2. Sit-down work counters are normally about 75 cm (30") high.

3. When chairs or stools are used with work counters or other laboratory units, there should be a difference in height of about 25-30 cm (10-12") from the top of the stool or chair seat to the top of the working surface.

4. Chairs with seats about 45 cm (18") high are normal for secondary school students as well as adults in general. Stools that can be adjusted from about 45 cm (18") to 68 cm (27") are available for purchase.

5. The distance between the top of a 90 cm-high work counter along a wall and the bottom of a wall unit 75 cm high should be 45 cm so the top of the wall unit(s) will be in line with the tops of other pieces of furniture, such as storage and display cabinets, which are normally 210 cm (7') high. Thirty-eight cm (15") are sufficient in cases where other pieces of furniture are not taken into consideration.

6. Many different materials are used to make tops (working surfaces) for science furniture*. These include

- Welded fiber—not recommended for wet areas, especially where sinks are installed underneath the tops, and where strong acids or heat are to be used
- Impregnated natural stone—recommended for areas exposed to heat, moisture, and acid
- Colorlith (has asbestos and portland cement base with vinyl wax coating)—resistant to heat, acid, and moisture; however, after wear has abraded the wax, water and chemicals will penetrate and cause staining. Restrict its use to physics laboratories; instruments and other items dropped on it are not as likely to break as when dropped on stone or epoxy resin tops.
- Epoxy resin (thermoplastic material)—most resistant of all materials discussed here; presently is most expensive. Sinks are commonly made from this material. Hydrofluoric acid will etch it slightly.

* Recommendations are those of the writer, based on my observations and knowledge of the various materials.

• Laboratory-grade melamine plastic laminate (specially formulated for laboratory use and laminated on plywood or chipboard)—recommended for dry areas at the junior high school level. Also suitable for dry desk/table tops at any level.

7. Counter tops that adjoin walls should have a curb (backsplash) along wall edge and on the ends where they abut a wall, an appliance, or a piece of furniture.

8. If cabinet doors and drawers are to have locks, master keys (one key fits all locks) should be obtained. An extra copy of the mas- ter key should be labeled and stored in the school office for safekeeping. A key cabinet should be placed in each room where there are locks on cabinet drawers and doors to alleviate the inconvenience of having to search for individual keys from a pile of keys in a drawer or box.

9. Security panels should be provided between locked drawers over locked cupboards to prevent unauthorized entry from the drawer opening above.

Listed below are some items pertinent to planning facilities for elementary school science:

- Flat-top working surfaces
- Working surfaces of material resistant to water, mild chemicals (e.g., vinegar, baking soda), and moderate heat
- Sources of water and electricity
- Appropriately coordinated seating and working surface furniture
- Sufficient storage and display space within the classroom
- Classroom designed so that "wet" and "dry" areas are evident
- Provision for teacher demonstrations

Miscellaneous

Provided in this section are some additional ideas to provoke further thinking and consideration by facility planners as they begin the process of planning science facilities:

1. Demographers in the late 1970s were warning that student enrollments would continue to decrease each year in the foreseeable future. This phenomenon, compounded by other factors such as increasing costs and community attitude toward facilities, has created the issue of modernization versus replacement of existing facilities. The most appropriate way to deal with the issue is through well-designed feasibility studies. The solution to this issue presents the design professionals and educators with a challenge to a degree with which they have never dealt.

Added to this is the factor of mobility: Facilities must be provided where students are. Society's mobility may maintain or even increase the demand for the construction of new facilities for years to come. Some usable buildings may have to be abandoned.

2. There is a trend toward greater use of public school facilities for adult education. Adult enrollment in educational activities is also on the increase. Design professionals and educators must heed the implications of adult education when planning for and designing new facilities.

3. To boost faculty morale and create convenience in placing material orders, securing resource speakers, arranging for field trips, and so on, a phone might be placed in each teacher's office. There should also be a phone in the science department chairperson's office. Phone lines for computer hookups are increasingly necessary, so future requirements should be noted here.

4. To conserve storage space, it may be desirable in some cases to place stacks of storage shelves on rollers or tracks so that they may be locked very close together. When something needs to be taken from or put on a shelf, a single stack can be rolled out into position where it can be approached from either side and then rolled back into storage position.

5. Due to the requirement of costly utilities in the science complex, the complex should be located so that additional rooms (space) and utilities can be added later at minimum cost if

student enrollment, curriculum changes, or organizational adjustments should demand expanded facilities.

6. The ability to darken the room is advantageous when experimenting with light, certain plants and animals, photochemical processes, and when showing films or slides. When designing facilities with these activities in mind, sunlight can be considered a contaminant. This might indicate the desirability of rooms without windows.

7. Fume hoods are normally installed in science rooms for ventilating purposes. They can also be used for ventilating storage rooms. It is not often done, but they can be installed in the wall which separates the classroom and storage room to serve both areas. When this is done, the fume hood must be of the type which can be entered from both sides. A similar arrangement can be accomplished to serve two classrooms by placing one or more fume hoods in the separating wall.

8. Many small schools do not have sufficient student enrollment to justify a separate classroom-laboratory for chemistry and for physics. Too often a mistake is made, this writer thinks, by designing a chemistry-physics room. The chemicals used, and some gases and vapors created in chemistry, can be devastating to physics equipment and supplies. A common storage room for physics and chemistry is undesirable and often proves to be uneconomical through the loss of equipment made inoperable by the corrosive action of gases and vapors. Physics might better be combined with biology or some other science course.

9. The myth that classroom teachers use only one basic method of instruction still exists in the minds of too many design professionals and educators. Such thinking helps to perpetuate the status quo in facility design and to hinder innovation.

References

Engelhardt, David F. (1968). *Aspects of spatial influence on science teaching methods.* Unpublished doctoral dissertation, Harvard University. (ERIC Document Reproduction Service No. L3 ED 023 262)

Engelhardt, David F. (1970, March). *Architectural and administrative considerations for science teaching, grades 9–12.* Paper delivered at the 1970 annual meeting of the National Science Teachers Association, Cincinnati, OH.

Gilliland John W. (1969, December). How environment affects learning, *The American School and University, 42,*48.

McVey, G.F. (1971). *Sensory factors in the school learning environment.* Washington, DC: Association of Classroom Teachers, National Education Association Publications.

National Council on Schoolhouse Construction. (1964). *NCSC guide for planning school plants.* East Lansing, MI: National Council on Schoolhouse Construction.

National Science Teachers Association. (1970). *Conditions for Good Science Teaching in Secondary Schools.* Washington, DC: National Science Teachers Association.

Peccolo, Charles. (1963). *Thermal environment and learning.* Digest of a dissertation. University of Iowa.

Richardson, John S. (1961). *School facilities for science instruction.* (2nd ed.)Washington, DC: National Science Teachers Association.

For a comprehensive coverage of planning facilities for science in secondary schools, refer to: *Planning of facilities for teaching science in secondary schools* (Paul H. Taylor, Ed.D.dissertation, Duke University, 1977).

Paul H. Taylor, a science educator, is the author and/or co-author of several articles on various science educational topics published in professional journals. He has taught science in junior and senior high schools, served as junior high school principal, and is currently the director of the division of science with the North Carolina Department of Public Instruction.

School Science and Liability

15

GARY E. DOWNS
IOWA STATE UNIVERSITY

TIMOTHY F. GERARD
SOUTHEASTERN COMMUNITY COLLEGE

JACK A. GERLOVICH
IOWA DEPARTMENT OF EDUCATION

To many science teachers, administrators, and attorneys, school science safety is a paradoxical term: the teaching of science involves pairing potentially hazardous materials with inexperienced, untrained students and staff. To aggravate this matter, the science learning environment often lacks the necessary and appropriate safety equipment. What are the safety implications in a situation like this? What are the legal complications?

Surprisingly, an analysis of data collected by Gerlovich and Downs (1981) indicates that science environments are generally among the safest places in schools. They found, for example, that of 1,042 Iowa school accidents reported between 1980–82, only 9 percent of these were science-related. Of these, 5 percent occurred in general science settings. During this same time frame, of 90 reported science accidents, 16 involved glass cuts, 10 involved another person in a science setting, and only 8 involved chemicals.

It seems that science teachers can avoid most safety and liability problems as long as they

- ensure that instruction and supervision are adequate
- maintain the environment properly
- remain knowledgeable of properties and hazards affiliated with the equipment and chemicals used in their classrooms
- anticipate safety problems and attempt to have them corrected o provide clear role models in the appropriate use of such safety equipment

Teachers should always weigh an activity's educational value against its hazard. If a spectacular but hazardous activity cannot be sufficiently altered to reduce the risk to coincide with its educational value, it should be eliminated from the science course.

The three authors of this chapter have, between them, written five books and numerous safety articles. In the confines of the space allotted, however, this chapter will focus primarily on two areas: legal liability and the learning environment.

Legal Liability

Safety should be everyone's concern. People who behave in an unsafe manner not only expose themselves to a greater risk of accident or ill health, but increase their chance of being held legally liable for injury to the property and health of others. For example, a careless driver endangers more than his or her own life; by also endangering the lives of others, he or she increases the chances of being legally liable in an accident. There is a direct correlation between safety and the conduct the law expects of us all.

The civil law expressed throughout the 50 states presumes that people have an obligation to behave reasonably where their conduct affects other people. This is an extension of the criminal law, which is designed to protect the lives and property of citizens. The proscriptions embodied in criminal law are considered undisputed specific dictates of reason. But, in a free society, it is neither possible nor desirable to specify everything that citizens ought to do to preserve order within society. Therefore, civil law evolved to further protect the lives and property of individuals from events which are not criminal, but may nonetheless be unreasonable. The protection is afforded through a process of awards to victims of unreasonable behavior, exacted in the form of judgments against those who caused damage by behaving unreasonably—or unsafely.

Simply put, anyone can be held legally accountable for the consequences of their unsafe actions. For those in science education, the lesson is that unsafe conduct in the laboratory may make one personally and financially responsible for any harm resulting from such conduct.

The legal principles which govern this civil form of accountability are much the same throughout the country, and apply uniformly to all sorts of conduct (Gerlovich, Gerard, and Hartman, 1988). The most basic principle is that one has a duty as a citizen to behave reasonably toward others, which translates into legal terminology as a duty owed to avoid negligent behavior. The law defines "negligence" as acting differently than a reasonable person would in a specific circumstance. It can mean either doing something unreasonable, or failing to do something reasonable. It may be helpful to think of negligence as carelessness.

The standard of accountability in any given circumstance is determined by what ordinary people (often a jury) deem to be reasonable. There usually exists a body of law, built up over time from previous, similar cases, which gives precedent to the present case. In arriving at its decision, a jury is guided by the opinions of experts familiar with the specific circumstances in which the accident took place. These experts testify based upon their specialized knowledge and experience as to whether certain conduct was reasonable in a particular situation. For example, if a lawsuit arises from an accident occurring in a chemistry laboratory, expert witnesses such as leading chemistry teachers and safety experts may testify as to whether the accident was caused by unreasonable conduct, and, if so, by whom. A body of case law then builds up around specific sets of facts, guiding the decisions in future cases with similar sets of facts (Gerlovich, Gerard, and Hartman, 1988).

How, then, should science educators conduct themselves in order to avoid being found negligent and held liable for damages arising out of an accident? Although the law does not say that accidents always result from negligence (they often happen through the fault of no one), there is a tendency in a complex technological society to try to assign fault and apportion liability accordingly This is especially true in education, where students are presumed to be under the care and protection of their teachers. A science educator, then, must conform to what other science educators would consider reasonable in order to minimize their risk of legal liability. This recommendation is largely common sense. For example, a science teacher who asked a student to pour water into concentrated acid to demonstrate its explosive effect would surely be found negligent. More technical matters, however, require judgement and testimony by other science teachers who are familiar with the given situation. The operative question revolves around what the consensus of opinion would be as to the reasonableness of this conduct by others in the science education profession. For this reason it is of the utmost importance that educators keep abreast of the developments in their profession in terms of both safety and the content they teach. Continuing education is essential to staying within the mainstream of opinion as to what constitutes reasonable behavior.

Thereafter, educators must accept their responsibility to implement safe conduct in three main areas: first is the duty to adequately supervise students, to "keep a watchful eye." Improper supervision is the single greatest cause of legal liability in science education. Proper supervision will prevent most accidents. The second duty is to inform students of all foreseeable and reasonable hazards. A teacher must tell students all that they need to know to participate safely in any given learning project; the appropriate and accurate dissemination of information relevant to student safety should be an integral part of lesson planning. The third duty is to maintain safe equipment and a safe environment in which students learn. All three duties pertain to the teacher's responsibility when in charge of students in a learning situation. Again, the duties must be performed according to the acceptable standards of the profession to insure protection from legal liability.

Of course, in addition to the common sense aspect of civil law, there do exist statutory or rule-specific safety requirements, such as those regarding eye protection. Failure to comply with these laws may result in an automatic finding of negligence against the teacher who does not comply. Thus, all laws, rules, and regulations must be carefully studied and observed in order to avoid being held negligent in an accident.

The Learning Environment

The best learning is that which relates concepts to stimulating, hands-on activities. In science, however, the benefit of learning must be weighed against the inherent risk of involving students in such activities. This weighing is done by the teacher and the supervisor.

The task of science supervisors and teachers is to determine an acceptable level of risk for all activities contained in the science curriculum. Supervisors should encourage classroom teachers to use science safety contracts (Gerlovich, Gerard, and Hartman, 1988) with their students, an effective way to establish mutual understanding of the importance of science safety.

Another effective safety communications technique is the strategic use of safety signs in science classrooms and laboratories. Such signs should be especially conspicuous and strategically placed to address such critical safety items as the use of cover goggles and the location of fire extinguishers, fire blankets, eyewashes, and drench hoses. Supervisors should ensure that both teachers and students know the location and retrieval process of safety equipment, especially fire extinguishers and fire blankets. Teachers must also know where to find and how to use the master shutoffs for water, gas, and electricity for their classrooms and laboratories.

The great majority of states have initiated eye protective equipment or "goggle" laws to protect the eyes of teachers and students while they are engaged in activities involving materials which could cause eye injuries. Teachers in states which do not currently have such laws should still insist that their students wear appropriate eye protective equipment when necessary as an example of what a "reasonable and prudent" science teaching professional would do under similar circumstances.

It is the responsibility of the teacher to remove any student who persistently ignores the rules to wear such specific safety equipment. Reasonable reinforcement might include developing a student safety contract that explains all facets of safety, and requiring students to sign it to signify their understanding of the items; placing safety signs which emphasize the wearing of safety goggles in strategic locations about the laboratory; and vocal reminders that equipment must be worn at the designated times and locations. At the end of this trail of prompts, the teacher must remove any student who disregards the given rules from the course in order to prevent injury to the offending student and/or those in the proximate area. Failure to remove a student from a science course following repeated student defiance of rules could place the teacher in a position of serious liability should the student or someone around be injured. This is a teacher responsibility that must not be taken lightly. If there is any possibility of eye injury, the teacher should err on the side of caution and require the wearing of protective eyewear.

Labeling of chemicals and supplies is another vital safety factor for which the supervisor is responsible. Supervisors should work with classroom teachers to develop an appropriate system of labeling all chemicals with the substance name, date received, ingredients, hazards, incompatibilities, and disposal date. One system gaining widespread use in schools is the National Fire Protection Association (NFPA) 704 Hazard Identification System. This system uses a hazard diagram to visually communicate the hazardousness of substances relative to flammability, reactivity with other substances, human health hazard, and any special problems. If the chemical supply contains unlabeled substances, they should be identified and then either properly stored or disposed of according to local, state, and federal standards.

The science supervisor should organize and implement an effective storage system for chemicals and supplies. The storage of chemicals can be made safer by providing

- isolation of incompatible chemicals
- protection of chemicals from excessive heat or cold
- proper ventilation
- security against unauthorized access (*Manual of Safety and Health Hazards in the School Science Laboratory*, 1980)

Separating equipment items from chemical supplies also increases the life of many types of apparatus and prevents chemical reactions from affecting their proper function.

It is assumed that all schools conduct periodic evacuation drills. In addition, the science supervisor should assist teachers in designing and practicing drills specific to the science setting. This provides students with hands-on learning of the correct procedure to follow in an emergency situation. Simulations can be formulated for specific science emergencies, such as chemical splash in the eyes or on a student's clothing, or an equipment fire. These emergencies may be acted out using a single student as the victim and his or her peers as safety monitors. Such simulations should be conducted periodically on an impromptu basis.

The science supervisor should also take an active role in planning and conducting safe science activities off school premises. He or she should work cooperatively with the classroom teacher in formulating the activity's purpose, teaching objectives, desired student outcomes, and evaluation of student achievement. The amount of adult supervision varies with the degree of danger involved in the activity, the novelty of the environment to be experienced, and the age of the students participating.

A signed permission form should be received from the parents or guardians of each student before their involvement in the activity. These forms should describe the type of school-sanctioned student transportation to be used, a description of the field site, the activities to be conducted, and the date and time of activity. Providing such forms to parents or guardians provides them with the opportunity to decide whether there are certain features of the activity in which their child should not participate. A student with hay fever, for example, might be prevented from studying the grassland ecosystem in the fall.

The supervisor should assist the teacher in conducting an on-site visit to the proposed study site before involving students in the activity, to acquaint the teacher with any possible hazards. All such hazards should be discussed with students before the visit. Appropriate safety equipment should be inspected to assure that it is functional, adequate, and that students can operate it. If the hazards exceed the educational value of the activity, or if necessary safety equipment cannot be provided, the activity should not be undertaken.

The science supervisor should assist the teacher in identifying appropriate student transportation for off-school premise activities. Only school vehicles or school-sanctioned vehicles should be used: using school-sanctioned vehicles assures that insurance is provided for teachers and students and that the school administration is apprised of the activity. In addition, school vehicles generally provide appropriate safety items for students.

The supervisor and the teacher must also ensure student protection at the visitation site. Pairing students is an effective method: Making one student responsible for his or her partner helps assure that help can be secured if an injury occurs. This arrangement is especially critical if students will be out of the teacher's sight at any time during the activity.

The science supervisor should assume much of the responsibility in making the environment safe for student learning. He or she should ensure that the above topics are addressed, in detail and within the context of the individual school district's setting. An excellent way to do this is by arranging for a qualified science education safety specialist to conduct a thorough safety inservice session for all science teachers. In addition, the supervisor should help establish a K–12 library of safety references such as those provided at the end of this chapter.

In summary, science supervisors and teachers are no different from any other professionals when it comes to avoiding legal liability. They must behave reasonably, use good common sense, employ the safe practices recommended within the profession, and avoid exposing students to hazards deemed unacceptable by qualified peers. The study of science periodically involves hazardous activities, and it is the professional and ethical responsibility of the science supervisor, an educational leader for the district, to assure that the danger involved in such activities does not exceed their educational value.

References

Gerlovich, J.A., Downs, G.E., et al. (1981). *Better science through safety*. Ames, IA: Iowa State University Press.

Gerlovich, J.A., Gerard, T.F., & Hartman, K. (1988). *The total school science safety system*. Des Moines, IA: Jakel, Inc.

Index. (1982). (9th ed.). Rahway, NJ: Merck and Company, Inc.

Manual of Safety and Health Hazards in the School Science Laboratory. (1980). Cincinnati, OH: National Institute for Occupational Safety and Health.

Pfaff, Robert C. (1985, November). Safety in the chemical laboratory: Chemical safety and emergency response in small schools. *Journal of Chemical Education, 62*(11), A282–A286.

School laws of Iowa (1982). Des Moines, IA: Iowa Department of Education.

Gary E. Downs is currently Professor of Elementary Science Education at Iowa State University. He has authored and/or co-authored books, papers, and articles on school science safety and curriculum development, among other subjects. His major research interests have been in the affective area of education and curriculum development. He has taught elementary through college levels and has been at Iowa State University since 1975.

Timothy F. Gerard is the Director of Personnel at Southeastern Community College, West Burlington, IA. He is an attorney with extensive experience in science education safety. He has taught philosophy at Iowa State University and Indian Hills Community College, and has assisted with several school safety seminars.

Jack A. Gerlovich is the state science consultant for the Iowa Department of Education. He has authored and co-authored books, papers, and articles related to school science safety, among other subjects. He has taught junior high through college levels and is an active member of many science education organizations.

Maintaining Living Organisms for Classroom Use

16

MICHAEL C. JACKSON
LEJEUNE DEPENDENTS' SCHOOLS

GRACE K. PRATT-BUTLER
LONG ISLAND UNIVERSITY / BROOKLYN CAMPUS

Both science students and teachers can profit in many ways by culturing living organisms. Culturing your own organisms is an inexpensive alternative to buying them from commercial sources; in actively caring for the organisms, students learn both laboratory skills and a sense of responsibility for various kinds of living things. This chapter describes basic principles involved in setting up a culture center for some commonly used vertebrates, invertebrates, and plants. Once you have some experience with the organisms described here, you may want to try growing organisms that require more specialized culturing techniques.

Getting Started

Begin by evaluating your program's needs. Which plants and animals are used in your science labs and demonstrations? Do any of these organisms have needs you can meet at school? Begin with what you know best.

Next, evaluate your resources. Enlist student assistance in planning the center and providing the active care the organisms need. You will need to determine equipment needs and possible sources: Students can be ingenious in finding materials and equipment that teachers sometimes overlook. Send "want" lists of simple household materials home with the students. Many parents will gladly donate glass containers, old aquariums, fluorescent light fixtures, plants, pots, and potting soil. You may also want to organize parent or community volunteers to help set up the center; contact local retirement groups for the names of people who might be willing to give valuable time and assistance.

Equipment Needs

A culture center needs containers of many sizes—commercial culture dishes, baby food jars with lids, glass or plastic jars, one-gallon plastic milk jugs, plastic trash cans, and plastic bags for storage and collecting. Other glassware items needed are lab bottles, micropipettes, and glass oven basters. Some possible sources for glassware and other items include the school cafeteria, hospitals, clinics, local businesses, and even yard sales. Fast-food chains purchase many items in reusable plastic buckets and jars that can serve as culture containers.

A large pressure cooker is required if your lab does not have an autoclave to sterilize glassware and solutions. Plastic containers can be sterilized with a diluted solution of chlorine bleach.

Other items needed are racks or bookshelves, fluorescent lights, aquariums, air pumps, cages, dishes, and water and electricity supply. A separate room for your culture center is desirable, though the corner of a classroom will do.

Water

As tap water and distilled water may contain minerals detrimental to many protozoans and other small animals, the water you use should be collected from springs (pondwater can be used as a last resort) in clean jugs and stored in the dark for a least a month: this helps settle sediments and assists in the sterilizing process. Alternatively, springwater can be boiled and cooled overnight. Keep a 15- to 20-liter supply in plastic jugs on hand at all times: these should be dated and the stock collected and rotated on a regularly scheduled basis.

Lighting and Weekend Care

Some organisms require light for successful culturing: place these cultures near a window or source of artificial light. Warm-colored fluorescent lights and those designed for plant growth are recommended (cool fluorescent lights may lack the wavelengths required by some organisms). Incandescent lights can also be used, and can serve an alternative source of heat over weekends. Use timers to turn lights on and off during weekends and holidays. Many organisms can withstand cold temperatures over short periods of time, but some larger plants and animals may not be able to survive these conditions: these should be "adopted" by students and taken home over long weekends and holidays. Parental permission and a list of requirements needed for sustaining the plants or animals should be part of the distribution procedure.

Invertebrates

Culture and equipment requirements are given below for invertebrates commonly used in life science or biology classes. Once proficiency is gained in running a living organisms culture center, other organisms can be added to the center's living materials list.

Protozoa

Initial cultures of protozoa such as *Paramecium* or *Euglena* should be ordered from commercial biological supply houses to ensure their purity. Many of these organisms can be collected from ponds, but pure cultures save time and effort unless you have the student labor force to isolate individual species with a microscope and micropipettes. Commercial cultures have been grown in containers and are more adaptable to classroom use. Culture media and solutions can also be purchased, but these can be made inexpensively in a culture center with materials usually available in a high school science class.

Paramecium caudatum are more easily cultured in dishes that stack. Pour 200 milliliters of aged springwater in each dish, add two grains of wheat (available from health food stores) and two stems of timothy hay 2–3 centimeters long. Stack these dishes in the pressure cooker, ensuring that the top dish is empty—this dish will keep the other cultures from drying out. Sterilize the materials for 15 minutes at 15 pounds of pressure. Allow dishes to cool overnight in the pressure cooker. To inoculate the dishes with commercial cultures, examine the culture under a dissecting scope and use a micropipette to transfer the organisms into the individual dishes. Stack cultures and place in dim to moderate light at room temperature (20°C).

Amoeba may be cultured following the same directions, but use three or four grains of wheat and omit the hay. Keep all cultures covered to keep out dust and prevent evaporation. Subculture every two to three weeks and discard old cultures.

Euglena sp. can be easily cultured by taking 500 milliliters of aged springwater and adding the following materials: 20 wheat grains, 15 rice grains, and 5 milliliters of powdered milk. Boil the solution for five minutes in a glass or enamel pan, then cover and cool solution overnight. Inoculate with a pure culture the next day. The culture can be kept in a glass gallon jar and located in a well-lit place. Keep covered and use a sterile glass oven baster to remove cultures for distribution and class use. This is one of the easier protozoans to culture and they can go without care for several weeks. Fresh cultures can be started from the old one following the same procedures.

Flat, Round, and Segmented Worms

Planaria can be cultured by placing collected animals in shallow containers of aged springwater. Change the water daily, and feed planaria with cho- -d beef liver or hard boiled egg yolk week

Roundworms can be cultured in the classroom by using vinegar eels. Pour approximately 3 liters of apple cider vinegar into a clean gallon jar. Add a peeled apple that has been cut into 6–8 pieces. After 2–3 days, inoculate medium with a pure culture of vinegar eels purchased from a commercial biological supply house. Keep container loosely covered. Remove cultures with oven baster. Cultures can be distributed to other classes in baby food jars. Replenish vinegar and apples as needed. Leave any debris on the bottom of the container.

Earthworms can be cultured in large styrofoam coolers, plastic trash cans, or deep trays filled with loamy soil that contains little clay or sand. Sprinkle corn meal on top of soil and mix the two together. Add earthworms that have either been collected or purchased from bait shops or supply houses. Keep soil moist but not wet. Add leaf litter to top of soil. Extra corn meal may be sprinkled on top of soil once a month for feeding. A wire mesh should be placed on top of the container to keep worms from crawling out. The culture may be kept outside in a protected place except in extremely cold weather. Change soil every 3 or 4 months.

Mollusks

Pond snails can be collected from the wild or purchased at tropical fish stores. Students with aquariums at home may have extra ones they would be willing to donate. Snails can be cultured in aquariums that have been set up for fish. Snails do not eat waste products, but do eat any food that fish leave. They can be fed small pieces of boiled lettuce leaves or regular fish food. Under favorable conditions, these mollusks produce many offspring. Excess snails can be crushed and used as a source of fresh food for hydra or fish.

Land snails can be collected from the wild by students. These can be grown in terrariums or gallon jars with 2–3 centimeters of soil. The snails should be fed once a week with lettuce or cabbage leaves. Keep containers clean to prevent mold or rot and keep soil damp, but not wet. Provide twigs and bark for snails to crawl on and leaf litter for cover. These can be cultured with other terrestrial organisms such as turtles, lizards, and snakes.

Daphnia can be cultured in gallon containers or aquariums using aged springwater and dehydrated cow manure. Add one gram of dehydrated cow manure to each 100 milliters of springwater, making a 1 percent solution. Culture organisms in glass jars that will hold 800 to 900 milliliters or more of solution. Allow solution to sit 2–3 days to allow bacterial populations to build: these will be a source of food for the daphnia. Inoculate the "manure tea" with a commercial supply of daphnia. Submerge the container containing the daphnia and pour the organisms out of the container underwater, otherwise they may get bubbles of air under their shells which will cause them to rise to the surface and die. (For this reason, daphnia should not be grown in aquariums with air pumps.)

Isopods are terrestrial crustacea known as pillbugs or sowbugs. They can be found in moist forest areas under rocks or logs, and can be cultured in terrariums with land snails or in plastic tubs or sweater boxes with 2–3 centimeters of loamy soil. Add the isopods, a few rocks and leaves for cover, and several slices of white potato for food and water every 2–3 weeks. Keep soil damp but not wet. Keep containers in a cool, dark place. Subculture as populations increase.

Insects

To culture mealworms (a kind of beetle larvae), use plastic buckets or gallon jars. Place 3–4 centimeters of wheat bran and several slices of white potato for food and water at the bottom of the container. Do not add any water as this will cause the bran to mold. Add mealworm culture. Cover container tops with cotton cloth or several layers of cheesecloth secured with rubber bands. Spray the cloth with water from a hand pump sprayer twice a day to keep culture from drying out. The cloth should be damp, not wet. Subculture as populations increase. Add strips of shredded paper to give adult beetles crawling room. Add new meal or bran each month.

Grow crickets in large plastic trash cans. Cover bottom with 6–8 centimeters of clean builders' sand. Keep sand dry. Cricket cultures can be fed dry dog food placed in a separate tray and changed every 4–5 days. Use pint jars inverted into a metal or plastic trough as a source of water. Fill this trough with cotton or foam rubber to provide a moist surface and to prevent crickets from crawling up into the jar and drowning. Water should be changed weekly. Remove dead crickets daily. If the container is not deep enough to prevent crickets from jumping out, cover it with a wire mesh screen. Egg cartons are an inexpensive material to use as cover for crickets: open with the egg pockets downward to provide the cover. Paper egg cartons are preferable to plastic, as the crickets will chew on them.

To promote egg laying, keep crickets in a warm place (30–35°C). Add a metal pie plate filled with damp sand and covered with wire mesh. Keep the sand in the tray moist. Female crickets will lay eggs in the wet sand; many will die once this task is completed. The wire mesh will prevent the adults from eating the eggs. The pan containing the eggs can be removed and placed in another large trash can. Maintain warm temperatures and keep the sand moist. The eggs will hatch in three or four weeks. Once the eggs hatch, follow the same feeding and watering procedures used with the adults. Crickets may also be fed vegetables or fruit, but any uneaten material should be removed before it decays. An incandescent light can be used to provide a source of heat on cold nights.

Plants

Many plants can be easily grown in classrooms. Care and culture of these can be found in most books on plants. Duckweed (*Lemna spp.*), for example, a small aquatic flowering plant, is easily cultured in classrooms. It can be grown on the surface of the water in fish tanks, but this may cut down on the amount of light reaching the interior of the tank and be detrimental to fish. It may also be grown in finger bowls or small fishbowls. Duckweed fares well in old aquarium water or water that contains some organic material. Culture solutions can be prepared by adding one gram of dehydrated cow manure to each 100 milliliters of spring water. Mix well and allow the manure to go into solution before using. Pour into smaller containers for culturing. Duckweed can be collected from ponds in some areas, or purchased from biological supply houses. Place cultures in well-lighted areas for normal culturing. Duckweed can be used in studies on the effects of different light requirements, various types and amounts of nutrients, or the effects of different types of water quality on plants.

Mammals

Certain animals are suggested here because they are easily cared for, comparatively safe, and can be housed indoors. The following discussion is only an overview of the care of these animals. The reference list at the end of this article or your school or local library should be able to provide you with the comprehensive information you need. A secure teacher with a calm approach is essential to providing successful, happy, learning experiences. The following animals are recommended:

- Rabbits and such rodents as guinea pigs, hamsters, gerbils, mice, and white or hooded rats
- Fish, especially goldfish and such hardy tropicals as guppies and sword tails
- Amphibians and reptiles such as frogs, toads, turtles, and certain newts and small snakes

Feeding should be done by students under supervision. Determine the nutritional requirements and feeding schedule of each species before it arrives at school. If the animal can accomodate it, extra food and water rations on Friday afternoon can be given. If weekend feedings are required, it is advisable to have the exact amount of food for each animal set aside in a paper towel or small container and labeled. Staff members who feed animals on weekends must have contingency plans for others to handle the feeding if emergencies prevent them from getting to the school.

Rabbits

Rabbits should be picked up by grasping the scruff of the neck with one hand and immediately supporting the body by shoving the other hand and forearm under the rabbit. Ears should *never* be used for this purpose. If rabbits are small and very tame, they can be picked up with both hands as one might a kitten or puppy. When frightened, rabbits thump their hind feet; when threatened, they can claw and bite.

Because it is their nature to burrow, rabbits should be kept off the ground. A safe hutch can be constructed of one-centimeter mesh wire. (Chicken wire is not strong enough.) The bottom should also be mesh wire and, if indoors, a metal tray of shavings, sawdust, or cat litter should be placed underneath to catch the droppings. For a medium to large rabbit, the hutch should be 120 by 180 centimeters to permit space for general exercise and stretching long hind legs. If a rabbit has the opportunity to exercise around the room, it can have a smaller hutch. The wire can be nailed tightly around two by two-inch or three by three-inch uprights connected to a strong frame. Although rabbits may gnaw on the wood, trying to gnaw metal can damage their teeth. One end of the hutch should be enclosed with solid material but with an entrance hole so the rabbit can retire to rest or avoid temperature changes. If the hutch is indoors and on legs, a top is not necessary. If it is low, however, it should have a wire mesh top to prevent students from dropping things in. A strong top is essential if the rabbit is kept outside: dogs and other predators are readily attracted. Remember, if a rabbit can get its head through an opening, the rest of its flexible body will follow. Rabbits tend to soil one corner regularly and so it is frequently unnecessary to clean the whole hutch daily. A little pine oil gives the hutch a fresh smell.

Guinea Pigs

Guinea pigs, or cavies, are excellent rodents for the classroom: They are small enough to live in a compact space, but large and strong enough to be handled easily by young children.

Guinea pigs can be picked up in the same way as rabbits. Their small size and usual desire to be petted and held tend to make it easier to scoop them up by placing one hand under them and the other over the back.

Guinea pigs can live in quarters similar to those for a rabbit, but the cage need only be 60 by 120 centimeters. Unlike rabbits, guinea pigs tend to soil their entire area. Shavings or other absorbent litter material usually lasts several days. Guinea pigs are usually odorless. While they like to stand on their hind legs against the side of the cage, they do not tend to climb. Freedom from drafts and sudden temperature changes are essential to their well-being.

Hamsters, Gerbils, Mice, and Rats

Although hamsters, gerbils, mice, and rats are nocturnal animals, they can adapt to daytime cycles with frequent handling and the stimulation of an active classroom or center.

Hamsters may be grasped by the scruff of the neck or by placing one hand over them, with the head sticking out out between thumb and forefinger. They may be held in both hands and usually enjoy cuddling into one hand. They are tailless.

Gerbils, mice, and rats are best picked up by grasping [illegible] tail close to the body with one hand and [illegible] immediately placing the other hand under the animal for support. The teacher, wearing thick gloves, should pick up any new animals a few times until they are accustomed to handling. Rats are not as tame as other animals when acquired. Most of these small animals like to be picked up and petted.

All of these rodents live very well in an aquarium tightly covered by mesh wire. All gnaw with their very sharp teeth. Shavings, sawdust, or litter material make an absorbent floor covering. Hamsters like a handful of shavings in one corner as bedding, especially if cat litter is used to cover the bottom. Provision for exercise is essential. Special cages with exercise wheels and trails may be purchased; wheels, tiers, small ladders, and swings, or a high resting spot are helpful to their well-being. They all like to scamper about and will use a small spring or ladder suspended from the top of the cage. All will use water bottles.

Baby Rabbits and Rodents

If you have not successfully separated male and female rabbits or rodents, newborns will result according to the schedule below.

Mother animals and newborns require privacy and special care. Consult your library or bookstore for more information if you expect such events in your classroom.

	Gestation Period (Average)	Number in Litter (Average)
Rabbits	*28–30 Days*	*4–8 (Born blind and hairless)*
Guinea Pigs	*63–65 Days*	*2–4 (Born fully haired, eyes open, nurse soon after birth)*
Hamsters	*16 Days*	*8 (Born blind and hairless, kept covered in nest)*
Gerbils	*23–24 Days*	*4–6 (See hamsters)*
Mice	*20–22 Days*	*8 (See hamsters)*
Rats	*21 Days*	*8 (See hamsters)*

Fish

Fish tanks are interesting additions to classrooms. General requirements for fish habitats include the following:

- A rectangular aquarium with straight sides is best because it provides greater air surface.
- A cover over the aquarium prevents dust and objects held by children from falling in, fish from jumping out, and is protection from sudden temperature changes.
- Water must be conditioned by an appropriate commercial product or left standing for a least 24 hours before being placed in the tank.
- Tropical fish need a light which, although helpful, is not necessary for goldfish.
- A pump and filter with glass wool and charcoal are recommended, along with white gravel or white pearl chips. At least 2 centimeters of sterilized sand should cover the bottom.

The aquarium should be placed in a permanent location, away from places where there may be extreme temperatures. Do not try to pick fish up by hand: use a small net. Watch that students do not try to pet the fish. When fish are fed, try to give them only what can be consumed in five to ten minutes. Consult a pet store owner if white fungus spots develop on the fish.

Goldfish

Goldfish are the easiest and hardiest fish to keep. Goldfish require 2 liters of water to a centimeter of fish. The most frequent causes of death are overfeeding and overcrowding. Water should be about 13°C; radical temperature changes are not recommended. Some light is necessary and cabomba plants can provide shade.

Eggs are laid ten to twenty at a time and hatch in three to seven days. Baby goldfish rarely hatch indoors, but the dark brown babies may be brought inside from outdoor pools.

Guppies

Guppies have a life span of about three years. If the classroom is cold, a heater should be used to keep the water between 21° and 26°C.

Since guppies bear live young, they are the easiest tropicals to culture. A female may produce up to fifty young every four to six weeks. The babies are rolled up when ejected from the mother, but unroll and swim to cover immediately. Cabomba plants provide a good hiding place so that the young aren't eaten. Better, separate young from adults as soon as possible. Give extra food to the adults when the young are born to reduce cannibalism. The babies should be fed a fine dry food, or finely ground adult food. (The back of a spoon makes a good grinder.)

Amphibians

Small amphibians such as newts, green frogs, and toads are easily kept. Keep species separate and do not house more than five or six of one species together. Animals in a group should be about the same size to prevent cannibalism.

As they grow larger, the skin of newts, frogs, and toads splits down the back and is eaten. These animals need a habitat with both water and land.

Newts

The eastern newt and the western newt are recommended. Newts hatch from eggs and the larvae have external gills for several months. While some eastern newts never leave the water, most spend their second year on land. These are often seen in the woods after a rain. After their sojourn on land, they return to the water. The western newt, larger than the eastern, appears to remain near the water during its life except for the spring breeding period, when it is found in the water.

An aquarium with enough conditioned water for swimming and submersion and enough land for walking about and an occasional sunbath makes a fine home for a newt or salamander. A tightly fitted mesh wire cover for the aquarium is recommended, however: the formation of these animals' feet permits them to walk up and out of a glass tank without a tight top.

Newts live well in a covered aquarium with one of the following arrangements: either have 7 centimeters of water in the bottom, 2 centimeters of plain gravel, and several mossy rocks, or soil and gravel covering the entire bottom and a water dish sunk so that the top is level with the soil. Water should cover at least a quarter of the area and moist moss, bark, or leaves added to provide shelter. Do not keep the tank in brilliant sun. An 8-liter tank is large enough for three or four eastern newts. The larger western newt should have more spacious quarters. Several do well in a 20-liter tank.

Frogs and Toads

The small green frog is the easiest to maintain, although the pickerel frog, leopard or meadow, and western chorus frog can also be housed satisfactorily. Keep only one kind of frog and those of about the same size together.

The male small green frog croaks, the female utters a soft squeaking sound. The two sexes may be readily distinguished because the ear (the round spot behind each eye) of the male is larger than its eye. Throats of the male are often yellow. The western or chorus frog is usually a dusky gray-green or brown and has a light under-surface and a light line along its upper lip.

A large tank with water and land enough for hopping makes a satisfactory habitat. It must be tall enough to permit jumping and tightly covered with wire mesh.

Toads can be easily distinguished from frogs. Their skin is dry to the touch and rougher than that of frogs, and contains a substance which predatory animals dislike. For protection, the toad may puff up, or go limp and play dead. The toad is not as good a jumper as the frog and tends to be slower. Its tongue is long and sticky and darts out for food. During cold winter months, it hibernates a foot or so under the surface of the ground.

Reproduction

The eggs or spawn of toads are laid in long chains of jelly-like material, while the eggs of frogs are laid in masses of a similar jelly-like substance. Males fertilize the eggs as soon as the spawn is laid.

Newt eggs are similar, but are laid singularly, usually on a submerged plant.

Place the spawn in a receptacle separate from the adults and filled with water of the same temperature as the spawn source. Leave the receptacle in the sun and, depending upon the temperature, the tadpoles or newt larvae will emerge from the eggs in a few days. Change some of the water daily and do not overcrowd the larvae or tadpoles; be sure the water added is conditioned and of the same temperature as that in the container.

Within a short time after emerging from the spawn or eggs, newt larvae or frog or toad tadpoles will fill out and small "feathery" gills can be seen. After a few days, newt legs are visible, but frog or toad legs will take longer. Hind legs are usually seen several weeks before front ones. When toads and frogs have three or four legs, and when newts are a centimeter long, add plants and some small sloping rocks to provide places to for them to emerge wholly or partially from the water. The ability to emerge is necessary because external gills are being replaced by internal lungs.

Tadpoles will suck at small drops of raw egg yolk, infusoria, other microscopic life, and bits of lettuce. Baby newts eat daphnia, infusoria, and other microscopic life.

Reptiles

Reptiles are cold-blooded animals classified into the following groups: turtles, snakes, lizards, alligators, and crocodiles. Some turtles and snakes may be kept satisfactorily.

Turtles

Turtles are the most easily kept reptiles. They can be purchased from pet stores, or captured in the wild. Consult local fish and game laws, usually available from the town clerk, to check on protection regulations.

Of the water turtles, the spotted turtle (one of the slightly varied sub-species of painted turtles), the western pond turtle, and the mud turtle are good pets. The green slider is, too, if permitted in your state. The diamond back terrapin may be kept like a water turtle, if a small pinch of salt is added to its water.

Of the land turtles, the eastern and western box turtle and the wood turtle are the most easily kept. Although more water loving, the Muhlenberg may be included with these.

The gender of a turtle can be determined by looking at the plastron, or undershell. That of the male tends to be concave. He has a longer tail and longer claws on his front feet than the female. Eggs are seldom laid by a female in captivity. When one does, she digs a hole with her hind feet in available soil, deposits the eggs, covers them, and ignores them. Water turtles in captivity occasionally lay infertile eggs.

Turtles can live for many years. They hibernate in nature, but tend to remain awake after a year or two in captivity if kept at room temperature and fed a small amount daily.

All turtles should have seven to eight hours of sun or artificial light daily. Lack of it will cause lethargy and may result in death. Their habitat should be placed away from extremes of heat, cold, and drafts. Check weekend temperature conditions. All turtles require sufficient water for submersion and drinking, land for walking, and wood or rocks for basking in the light. Keep only turtles of approximately the same size together.

Turtle water should be conditioned by standing for at least twenty-four hours before being put into the tank. An adult water turtle of 8–12 centimeters does well in a 30-liter aquarium with land enough—soil, rocks, twigs—to meet its needs. Water turtles feed in the water, land turtles on land. The latter require sufficient land for walking about and water enough for submersion. A receptacle sunk to its top in the soil can be used, or a tank with several inches of water can have a land area built up out of the water. Adult land turtles may be maintained in a tub or large (60 by 100 centimeters) wood box.

The turtle should be accustomed to being handled before children pick it up. When frightened or attacked they tend to pull head, tail, and legs into their shells, and may give a sharp bite before doing so.

Turtles can exist when fed only three times a week, but daily feeding is recommended when children are involved. Turtles tend to look for their food in the same place. They will grasp food from a pointed stick. Check with your library or pet store for a diet appropriate for your turtle species. Remove any uneaten food after fifteen minutes.

If a white fungus spot appears on the shell, especially the plastron, place the turtle in separate quarters in water to which a pinch of salt has been added.

Snakes

Small snakes are interesting pets, provided their needs are met. Three small snakes are suggested: the garter, the ribbon, and the green grass snake. These snakes eat small worms, ant eggs, or insects. Snakes may not need to feed every day, especially after a large meal. Snakes move swiftly and must be handled carefully. They have no ears, but are very sensitive to vibrations and have sharp eyes. They have long tongues with which to feel and to bring objects into the mouth where they have organs sensitive to smell. They can move each half of the lower jaw separately.

Snakes must have tight quarters. Large jars or aquariums with small mesh wire tops may be used for habitats. A screen cage 25 by 25 centimeters and 30 centimeters high is also suitable for the average size snake. A few plants and some moist growing grass for grass snakes to curl up in are necessary. A few sturdy plants, upright sticks, or large twigs are important for snakes to wrap around. A container of water on the floor of the habitat and an elevated shelf area are necessary. Rough bark or a rock is helpful for snakes to rub against when they begin to shed.

Hopefully this chapter will give encouragement toward maintaining living organisms in the classroom. Hands-on experience with living organisms is essential for understanding living processes and interrelationships; such learning experiences also teach students the fundamental concepts of ecology and conservation. Teachers must be sure that they and their students also observe the tenets of humane animal care and treatment. Please refer to NSTA's "Code of Practice on Use of Animals in Schools" and *How to Care for Living Things in the Classroom* (1978).

References

Carolina Biological Supply Company. (1982). *Carolina arthropodes manual.* Burlington, NC: Author.

Daniel, Lucy. (1983). *Culturing and maintaining living organisms.* Rutherfordton, NC: Rutherford County Schools.

Hampton, Carol, Hampton, Carolyn, Kramer, David, et al. (1986). *Classroom creature culture: Algae to anoles.* Washington, DC: National Science Teachers Association.

Hauser, J.T. (1986). *Techniques for studying bacteria and fungi.* Burlington, NC: Carolina Biological Supply Company.

Hummer, P., Kaskel, A., Kennedy, J.E. ,& Oram, R.F. (1986). *Probing levels of life: A laboratory manual.* Columbus, OH: Merrill Publishing Company.

James, Daniel E. (1978). *Culturing algae.* Burlington, NC: Carolina Biological Supply Company.

Morholt, E., Brandwein, P. F.,& Joseph, A. (1958). *Sourcebook for the biological sciences.* New York: Harcourt, Brace and World.

Orlans, F. Barbara. (1977). *Animal care from protozoa to small mammals.* Menlo Park, CA: Addison-Wesley.

Pratt, Grace K. (1963). Developing concepts about science in young children. *Science and Children, 1*(4), 21–22.

Pratt-Butler, Grace K. (1978). *How to care for living things in the classroom.* Washington, DC: National Science Teachers Association.

Pratt-Butler, Grace K. (1975). *The three-, four-, and five-year-old in a school setting.* Columbus, OH: Charles E. Merrill.

Pratt-Butler, Grace K. (1951). *Why not enjoy a pet rabbit?* (Pamphlet.) (Available from author, 5166 Post Road, Bronx, NY 10471.)

Whitten, Richard H., & Pendergrass, William R. (1980). *Carolina protozoa and invertebrates manual.* Burlington, NC: Carolina Biological Supply Company.

Michael C. Jackson, a science educator, has supplied many schools in his area with living materials from a culture center he set up in 1975. Although his main interest is elementary science education, he has taught high school and college courses in biology and horticulture. His other interests are in marine science and the academically gifted student. He has been the Science Coordinator for the Lejeune Dependents' Schools at Camp Lejuenc, North Carolina, since 1981.

Grace K. Pratt-Butler has served as teacher, professor, and administrator. She has taught classes from pre-school through the graduate university level, and is an author, lecturer, and panelist in several fields, and, in science education, has stressed learning experiences with living animals. She recently retired from Long Island University, Brooklyn Campus.

What Should the Science Supervisor Know About Evaluating Programs and Teachers?

NSTA Guidelines and Standards for Evaluating Science Programs

17

BURTON E. VOSS
THE UNIVERSITY OF MICHIGAN

A new trend in science education improvement began in 1975 when the National Science Teachers Association published the first *Guidelines for Self-Assessment of Secondary School Programs.* Until then, national goals, generic standards, and non-specific strategies for improving science education had been the mainstay of books and reports on the subject. This "hands-on" publication finally met the need for one complete document that would "put everything together," enabling concerned persons to conduct a comprehensive examination of science teaching in their particular school. The task force which compiled the document drew heavily on earlier NSTA publications and thoroughly reviewed the areas of science education research, theory, and practice. The response was positive and demand was great; NSTA published a revised, expanded version in 1978. That same year, the National Science Foundation supported an NSTA-New York State Education Department Conference on Middle/Junior High Science, using *Guidelines* as the major evaluative framework. The latest version (in press) broadens the scope to address the many school districts required by Public Law 98–377 to do a needs assessment for funding requests, updates the high school guidelines, and includes a new section on elementary and middle school guidelines.

What are the *Guidelines?*

The *Guidelines* contain suggestions for closing the gap between an existing science education program and a desired program. Compiled by a task force of science teachers and science educators, the book provides a means for comprehensive examination of the science program for any school in any district, and teaches educators about their own situation. With input from the reader, the book helps determine local, community, and national science education goals; whether the school in question meets them; teacher inservice needs; content updating for teachers; and teacher qualifications in the subjects they teach.

It also includes statements and suggestions for model science programs drawn from a variety of sources: *Project Synthesis* (1977), a summary of findings related to the desired states of science education and the actual state;

Meta-analysis of Science Education Research (1983); *The Search for Excellence* conducted by the National Science Teachers Association (1983); federal reports such as *A Nation at Risk* (1983), and *Educating Americans for the 21st Century* (1983); *Research Within Reach* (1985); and annual reviews of research in science education published in *Science Education*.

The NSTA position papers on *Science, Technology, Society: Science Education for the 1980s* (1982), *Science Education for Middle and Junior High Students* (1987), *Working Conditions for Secondary Science Teachers* (1987), and *Preschool and Elementary Science Education* (1987) also provided a major contribution.

The development of self-assessment materials becomes crucial in light of the fact that most states will require school districts to undertake a needs assessment of their science program to highlight problems and identify program strengths. Under the proposed guidelines for funding purposes in science, Public Law 98–377 (State Grants for Strengthening the Skills of Teachers and Instruction in Mathematics, Science, Foreign Languages, and Computer Learning), local education associations may need to file an assessment of science needs with their respective state departments of education. States will fund local education associations' needs based upon criteria determined by the state. Thus, the self-assessment *Guidelines* provide an essential service to school districts, especially in rural areas with small schools and little science education leadership, or larger districts with no science supervisors or coordinators. The *Guidelines* perform a leadership function by focusing on the skills, attitudes, curriculum goals, and so on that lead to desired goals of science education for all students.

The Mechanics of Program Evaluation

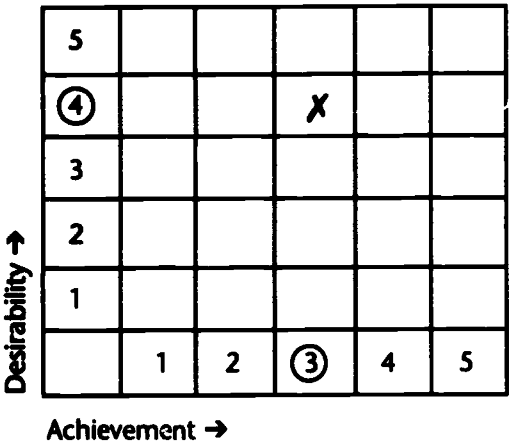
The *Guidelines* consist largely of statements that are to be evaluated by the faculty of a school and all teachers of a particular level—elementary, middle/junior high, high school. Examples of the statements are

- Science instruction includes the uses and abuses of technology.
- My elementary science instruction emphasizes hands-on learning.
- Elementary science instruction includes many problem-solving activities applicable to the daily life of students.
- The content and nature of the science program is determined by a K–12 science committee.
- I evaluate a student's progress in such a way as to minimize the negative effects of a reading difficulty.
- A part-time resource science specialist is provided at each elementary building to catalog, organize, order, etc., all science materials.
- I have science inservice at least twice a year.
- A fully equipped science laboratory is set up in every elementary building.
- Adequate release time is provided for science workshops during the school day.

Teachers or supervisors are asked to evaluate each statement in two ways: first, how *desirable* is the aspect in the given school or district? Second, to what degree has the school or district *achieved* the goal in question?

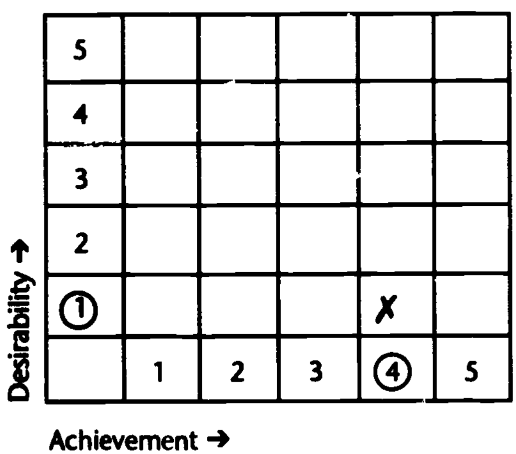
At the right of each item is a small matrix in which the rating is recorded. The vertical axis represents desirability, higher ratings at the top, lower at the bottom. The horizontal axis represents local achievement, lower at the origin, higher moving out to the right. Circle the rating that you wish to give to achievement. Then, for the score on this item, place a check mark in the box where these ratings intersect. Thus, an item that was deemed highly desirable but only moderately achieved would be recorded as follows:

Figure 1



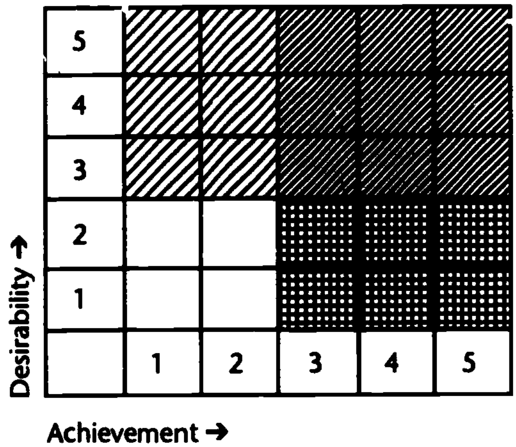
An item considered undesirable, but present to a high degree would be recorded as follows:

Figure 2



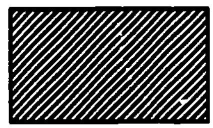
Further clarification of the Desirability/ Achievement rating is shown below. The shaded areas in the 5 × 5 tables represent the concerns, strengths, and so on determined by individual teacher ratings.

Figure 3

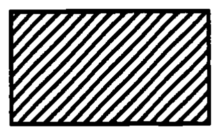


Interpretations of the shaded areas are:

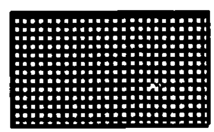
Scores in this area of the matrix indicate important goals being achieved and undesirable features being avoided.



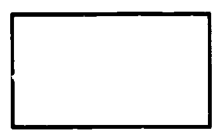
Scores in this area indicate items on which existing performance or conditions fall short of expectations.



Scores in this area reflect items on which more time, energy, and resources may be being spent than are justified by expectations.



Scores in this area represent rather neutral items which probably deserve little or no further attention.



Newer methods now involve the use of electronic scoring sheets for collecting and processing data. The electronic scoring sheets are read and data are then processed through SPSS computer programs. First, a 5 × 5 table is produced to show overall percentages in each cell. Then another SPSS program further reduces the data into 2 × 2 tables according to the criteria described for the various shaded areas of the 5 x 5 table. The 2 x 2 table easily advises you of the strengths of your program and its concern areas (those where a high desirability/low achievement is pictured).

It is projected that the self-assessment procedures will be completely computerized in the near future. Plans are under development for NSTA to package and sell the program on a computer disk.

Figure 4

Example of 5x5 Table
Anycity Middle School Science Needs Assessment: Cross Tabulation of 5x5 Tables

1069 Instruction-Desire Item 35

Desirability	Achievement 1	2	3	4	5	Row Total
Column Total	1 4.3	3 13	6 26.1	10 43.5	3 37.5	23 100
5	1 12.5 100		1 12.5 16.7	3 37.5 30	3 37.5 100	8 34.8
4			2 22.2 33.3	7 77.8 70.0		9 39.1
3			3 100.0 50			3 13.0
2		2 100 66.7				2 8.7
1		1 100 33.3				1 4.3

Example of 2x2 Table

1069 Instruction-Desire Item 35

1069 \ 1070 (Count / Row Pct / Col Pct)	No 1	Yes 2	Row Total
1 Not Desirable	3 100.0 75.0		3 13.0
2 Desirable	1 5.0 25.0	19 95.0 100.0	20 87.0
Column Total	4 17.4	19 82.6	23 100.0

Faculty consensus is often determined by a 75 percent level of agreement. If 75 percent of the faculty rate the statement in the desirable-achievement cell, a strength is determined; if 75 percent rate a statement desirable but not achieved, a concern is identified. Of course, school districts may establish their own standards.

Faculty committees can then evaluate the data and establish program strengths and concerns. Priorities for program improvement can be established and routed through district procedures for program improvement (see Appendix).

Considerable time will be needed to assemble the teams required, to hold preliminary meetings and discussions, to set work procedures and schedules, and, finally, to do the assessment.

Science teachers are the catalyst in this process. The improvement of science education must begin at the local level, and self-assessment is a critical means of achieving this goal. By 1989, NSTA will have sets of materials available for evaluating elementary science, middle/junior high science, and high school science programs to assist schools in meeting science education goals.

Appendix: Team Planning for Program Improvement

Based on the Self-Assessment and all sessions that your team members have attended, within your science program 1) Identify the major areas of concern; 2) Establish priorities; 3) List possible solutions; 4) Designate person(s) who will monitor progress on solution; and 5) Develop a progress time line. Make a report to the other team members. A follow-up meeting will be based on this report.

Area of Concern	Priority	Possible Solution	Person(s)	Time line

References

Harms, N., & Yager, R. (Eds.). (1981). *What research says to the science teacher.* (Vol. 3). Washington, DC: National Science Teachers Association.

Holdzkom, David, & Lutz, Pamela (Eds.). (1985). *Research within reach: Science education.* Washington, DC: National Science Teachers Association.

Meta-analysis of science education research. (1983). *The Journal of Research in Science Teaching, 20*(5), 377–509.

National Commission on Excellence in Education. (1983). *A nation at risk: The imperative for educational reform.* Washington, DC: U.S. Government Printing Office.

National Science Board Commission on Precollege Education in Mathematics, Science, and Technology. (1983) *Educating Americans for the 21st century.* Washington, DC: National Science Foundation.

National Science Teachers Association. (1970). *Annual self-inventory for science teachers in secondary schools.* Washington, DC: Author.

National Science Teachers Association. (1982-1988). *Focus on excellence.* (Vols. 1-17). Washington, DC: Author.

National Science Teachers Association. (1978). *Guidelines for self-assessment of secondary school science programs.* Washington, DC: Author.

National Science Teachers Association. (1987). *Preschool and elementary level science education.* (NSTA position statement). (Available from the National Science Teachers Association, 1742 Connecticut Ave., NW, Washington, DC, 20009.)

National Science Teachers Association. (1971). *School science for the seventies.* Washington, DC: Author.

National Science Teachers Association. (1987). *Science education for junior high and middle school students.* (NSTA position statement). (Available from the National Science Teachers Association, 1742 Connecticut Ave., NW, Washington, DC 20009.)

National Science Teachers Association. (1985). *Science Technology Society.* Rodger W. Bybee (Ed.). (Yearbook). Washington, DC: Author.

National Science Teachers Association. (1987). *Standards for the preparation and certification of teachers of science, K-12.* (NSTA position statement). (Available from the National Science Teachers Association, 1742 Connecticut Ave., NW, Washington, DC, 20009.)

National Science Teachers Association. (1964). *Theory into action.* Washington, DC: Author.

National Science Teachers Association. (1987). *Working conditions for secondary science teachers.* (NSTA position statement).(Available from the National Science Teachers Association, 1742 Connecticut Ave., NW, Washington, DC, 20009.)

Novak, J. (Ed.). (1972). *Facilities for secondary school science teaching: Evolving patterns in facilities and programs.* Washington, DC: National Science Teachers Association.

Showalter, V. (Ed.). (1984). *Conditions for good science teaching in secondary schools.* Washington, DC: National Science Teachers Association.

Burton E. Voss has been a science educator at the University of Michigan since 1963. His major interests in research and development have focused on instruction interaction analysis, science attitudes, inservice teacher education, curriculum development, science program evaluation, and most recently, on the use of microcomputer simulators for analyzing teaching strategies. He has been involved in NSF programs, Chautauqua science updates, and the development of new field biology laboratories. The self-assessment project has been one of his major activities for NSTA.

An Effective and Positive Evaluation Program 18

ESSIE C. BECK
JEFFERSON PARISH PUBLIC SCHOOL SYSTEM

Today's parents and taxpayers demand educational accountability. Perhaps because of their discontent with the public schools, many believe that falling test scores reflect pupils' inability to read, write, or do math and science adequately.

State legislatures are mandating the systematic evaluation of teachers. Generally, teachers are not opposed to evaluation itself; they are mostly concerned that it be fair and appropriate. To many teachers who have had experiences with administrators who were inadequately prepared or trained to do evaluations, however, the term "evaluation" has a negative connotation.

Evaluation Guidelines

It is widely accepted that any instrument for evaluation can be abused. Abuse clearly occurs, for example, when the evaluator makes a judgment and assigns an item rating to an individual without sufficient observation or documented evidence. Joint evaluation by administrator and teacher, following an established procedure, protects both.

Just as students are unique individuals with certain strengths, needs, and capabilities, so are teachers. Too often, evaluative measures omit this essential aspect of the teaching-learning situation. Ideally, evaluation should be conducted as a positive process, emphasizing strengths and offering constructive suggestions for overcoming weaknesses. The following questions will help administrators and teachers make evaluation a positive process.

1. Does the evaluation system focus on not only the teacher's skills, but also on the entire range of factors affecting the quality of teaching and learning, including program and curriculum, laboratory and safety facilities, student/teacher relationships, teacher/administrator relationships, and working conditions?

2. Is the purpose of the evaluation system to improve the quality of teaching and learning? Is the system informed by the goals and objectives of the school district?

3. Has the evaluation system been developed cooperatively by representatives from all of the groups evaluating and being evaluated?

4. Is the evaluation system carried out as a cooperative activity designed to establish rapport and communication between evaluator and teacher?

5. Does the evaluation system help the teacher to identify the scope of duties and prerogatives and clarify the relationship of personal and professional objectives to objectives of the school district?

6. Does the evaluation system include self-assessment, designed to motivate the teacher to improve instruction?

7. Is the evaluation system diagnostic rather than judgmental, thus defining the dimensions for inservice experiences?

8. Does the evaluation system establish, in writing, clear ground rules and follow-up procedures for both teacher and administrator?

9. Does the evaluation system require that adequate records be kept of all phases of the process? Are these accompanied by comprehensive contractual due process provisions?

10. Does the evaluation system encourage experimentation, creativity, and flexibility on the part of the teacher, rather than conformity to someone else's conception of what constitutes "good performance"?

11. Do all those concerned know the details and process of the evaluation before the evaluation begins?

12. Is the evaluation system realistic in terms of time and funds for implementation?

Teachers and administrators should sit down together to assess their needs, define goals, and establish the means to accomplish them. Evaluation policies, criteria, and procedures should be specifically designed for a particular school setting. Therefore, any evaluation of performance should be based on both mutual understanding and the objective acceptance of a program. Making evaluation a cooperative communication project can affirm that it is a growth experience for teachers, not one which puts them on the defensive and threatens their self-confidence.

One Evaluation Program

When developing an evaluation process and instrument, one cannot replicate another school district's program, but an antecedent can be used as a pattern. For a program to be successful, local concerns must be addressed.

The Jefferson Parish School System developed a teacher evaluation program that has served as a model to other districts in Louisiana and across the nation.

In the early stages of developing the Jefferson model, a cadre of personnel was assembled. This cadre included representatives from assistant superintendents, principals, teachers, supervisors, and professional organizations. The development of our program took time before it was functional. The program is continually monitored, reviewed, and revised as necessary for effectiveness.

The program in Jefferson was originally developed for nontenured teachers; since 1977, when Louisiana mandated a statewide accountability program, the same procedure has been followed for teachers with tenure as well.

Principals and central office personnel are involved in the evaluation process. They follow the systematic procedure given below:

Principal:

1. Principal or principal's designee holds an initial conference with the teacher to outline school and parish policies, to discuss the teacher's goals and objectives as developed by the teacher, and to discuss the principal's role in the evaluation process. (Initial Conference form, Appendix I)

2. Principal or administrative designee must make a minimum of one classroom observation each semester. (Personnel Observation form, Appendix II)

a. After every observation, a conference is held with the teacher. Both positive reinforcement and suggestions for improvement are offered. If curriculum support is needed, teacher and principal must concur or at least the teacher must be advised of the request.

Additional observations and conferences may be warranted. (Conference form, Appendix III)

3. Principal holds a conference at the completion of the school year and makes a final summarization. The teacher also provides a final evaluation. (Final Evaluation form, Appendix IV)

Central Office Personnel:

1. Initial conferences, in groups or individually, are held by the central office designee. The teacher is informed of criteria of expected performance and provided with copies of the job description and the evaluation process.

2. Evaluator conducts at least one classroom observation and holds a post-observation conference before January 16. The evaluator is not limited, however, to one observation and conference. Additional observations and conferences may be warranted and should be conducted.

3. Provision is always made to allow the observer and the teacher to make pertinent comments regarding the observation. (Indicators for Assessing Teacher's Performance, Appendix V)

If the principal and evaluator determine that a teacher's performance has been evaluated as "needs improvement," a professional assistance schedule is issued. The professional assistance schedule serves as notification that the teacher's performance has been identified as needing assistance. Specific recommendations for correction of cited performance area(s) are made to the teacher. The teacher is advised of his or her responsibility to correct performance area(s) cited for professional assistance and given a target date for improvement. (Professional Assistance Schedule, Appendix VI)

An appropriate action plan is outlined for the teacher identified as needing professional assistance. The teacher is given several opportunities to participate in professional growth activities to correct performance areas identified as needing improvement. These professional activities can be selected by the teacher or recommended by the evaluators.

Activities for Professional Growth

- On-the-job professional assistance from evaluator, immediate supervisor, resource personnel, and/or consultants
- A professional growth day
- Workshops, seminars, conferences, and in-service training activities
- Faculty study groups at the school level
- University courses offered in school system buildings
- Serving on professional or job-related committees
- Use of audiovisual and library materials available through the school system
- Sabbatical leave for professional growth
- Intra- and interschool/department visits

The teacher may be placed on Assistance Level II if, after the "Conclusion Date," (a date mutually decided upon, by which performance will have been improved) satisfactory performance has not been attained. A conference is held with the teacher to inform him or her of the continuation of professional assistance.

At the conclusion of the Assistance Level II date, the teacher's employment can be terminated if he or she is found to be incompetent, or if his or her performance is found to be detrimental to the educational growth of students. Due process procedures are always implemented. The due process must always provide evidence that teachers have received assistance from the principals, evaluators, and science supervisors or consultants.

An effective evaluation program should improve the learning experiences of students, foster positive interpersonal relationships among all educators, provide reliable information for decision making, improve public opinion, and increase support for public education.

References

Davis, Barbara S. (1985, Summer). Accountability: Whose? *Delta Kappa Gamma Bulletin, 51*(3), pp. 21–27.

Editors. (1980, September). Front lines. *The Executive Educator, 2*(9), 6-11.

Morel, Ralph. (1972, October). Accountability. *Louisiana Schools, L*(2), 34–35.

New approaches in evaluation of school personnel. (1972, May). NEA *Research Bulletin, 50*(2), 40–44.

Personnel evaluation program: 1974–1986 (1965). (Available from Jefferson Parish School Board, 501 Manhattan Blvd., Harvey, LA 70058)

A special issue of NEA Today. (1986, August). (Annual review, 1986–87). *Today's Education (5) 1.*

Essie C. Beck, a science educator, has taught both junior high and high school students. Since 1984 she has been the personnel evaluator and supervisor for Jefferson Parish Public Schools. She was on the study team that prepared NSTA's "Guidelines for Self-Assessment," and is currently working on its revision. She was NSTA's first Director of Supervision, 1974–75, and was president of National Science Supervisors Association 1980–81. The main focus of her work is on self-assessment, evaluation, and supervision.

Appendix I

INITIAL CONFERENCE FORM

SESSION 19____ -19____

EMPLOYEE:____________________ SOC. SEC. #:____________________

POSITION:____________________

EVALUATOR/IMMEDIATE SUPERVISOR:____________________

POSITION:____________________

DEPARTMENT/SCHOOL:____________________ DATE:__________

I. A. I have reviewed and received a copy of the Evaluation Packet:

____
SIGNATURE

B. I have reviewed and received a copy of the Job Description:

____
SIGNATURE

II. Statement of Goals:

____

III. Statement of Objectives (Objectives must be stated in measurable terms)

____

IV. Employee Comments:

____

V. Evaluator Comments:

____

I have read and received a copy of this form. Signature does not imply agreement or disagreement with content.

EVALUATOR/IMMEDIATE SUPERVISOR DATE EMPLOYEE DATE

SUBSEQUENT INDIVIDUAL CONFERENCE REQUESTED ☐ Yes ☐ No

By:____________________
NAME

Use Additional Comments Page for Follow-up Conference.

Appendix II

PERSONNEL OBSERVATION FORM

SESSION 19___ -19___

Scheduled ( ) 0-3 ( )
Unscheduled ( ) 4+ ( )

OBSERVEE:________________ POSITION:________________

OBSERVER:________________ POSITION:________________

SCHOOL/DEPARTMENT:________________

TIME OF OBSERVATION: ________________ to________________

DATE:__________

I. Description:

____
____
____

II. Post Observation Conference Date:________________

Observer Comments:

____
____
____

Observer Comments:

____
____
____

III. Request for Support Personnel ☐ Yes Specify:________________
If checked, forward copy to Personnel Department.

I have read and received a copy of this form. Signature does not imply agreement or disagreement with content.

________________________ ________________________
OBSERVER DATE OBSERVEE DATE

Appendix III

CONFERENCE FORM

SESSION 19____ -19____

EMPLOYEE:______________________________

SCHOOL/DEPARTMENT:______________________________

POSITION:______________________________ CONFERENCE DATE:__________

I. Description of Event: (Be specific)

____

____

____

____

II. Comments and/or Resolutions: (Immediate Supervisor)

____

____

____

____

III. Comments: (Employee)

____

____

____

____

IV. Administrative Conference(s) Attached: ☐ No ☐ Yes

V. Excessive Absence/Tardiness ☐ Yes

VI. Request for Support Personnel ☐ Yes Specify:__________

Support requested by: ☐ employee ☐ supervisor
(If checked, forward copy to Personnel.)

I have read and received a copy of this form. Signature does not imply agreement or disagreement with content.

______________________________ ______________________________
IMMEDIATE SUPERVISOR DATE EMPLOYEE DATE

Appendix IV

FINAL EVALUATION FORM

0-3 ( )
4+ ( )

SESSION 19____-19____

EVALUATEE:__________________ . ____________ SOC. SEC. #:____________________

POSITION:____

EVALUATOR:____

POSITION:____

DEPARTMENT/SCHOOL:______________________________DATE:____________

I. Statement of Accomplishment of Goals and Objectives (Evaluator)

____

____

II. Evaluation of Evaluator's PerformanceE (Evaluator)

____

____

☐ Satisfactory ☐ Needs Improvement ☐ Unsatisfactory

____

____

III. Recommendation for Professional Growth (Evaluator)

____

____

IV. Evaluatee Comments

____

____

I have read and received a copy of this form. Signature does not imply agreement or disagreement with content.

______________________________ ______________________________
EVALUATOR DATE EVALUATEE DATE

Complete for 0-3 Year Employee: Starting Date in Jefferson: ____________

In accordance with the prescribed procedures of the Jefferson Parish Public School System, after the evaluation of this employee with 0-3 years experience, I hereby recommend that the Jefferson Parish Public School System

☐ re-employ ☐ not re-employ

______________________________ ______________________________
EVALUATOR DATE 0-3 YEARS EVALUATEE DATE

Appendix V

Following is a list of indicators which are among the criteria used by the evaluator to assess teacher's performance.

Management and Control

The degree to which the teacher:

1. Implements efficient procedures for distributing and collecting materials.
2. Implements procedures for checking students' work (student accountability).
3. Implements appropriate procedures for student movement.
4. Enforces system, school, and classroom rules.
5. Appropriately and immediately disciplines disruptive students.
6. Is aware of the activities of each student.
7. Is aware of potential problems.
8. Is mobile.
9. Checks attendance.
10. Maintains an orderly and neat classroom.
11. Controls unnecessary noise and student conversations.
12. Requires students to be prepared with materials necessary to carry on the day's work.
13. Maintains seating arrangement.

Technique

The degree to which the teacher:

1. Reviews previously presented concepts.
2. Keeps students productively involved in the learning process.
3. Provides for student accountability (e.g., checking assigned work, questions students.)
4. Presents lessons in an orderly, sequential manner.
5. Is aware of student needs and behaviors.
6. Uses appropriate reinforcing techniques.
7. Provides for individual levels of achievement, ability, and interests of students. (Individualization.)
8. Uses appropriate materials and audio-visuals.
9. Maintains orderly, well-defined, functional learning centers.
10. Modifies techniques and presentation considering student progress, behavior, and needs (appropriate methodology).
11. Is impartial.
12. Minimizes distractions.
13. Is creative.
14. Capitalizes on spontaneous classroom situations consistent with objectives.
15. Uses appropriate resources.
16. Is aware of what has been accomplished.
17. Makes appropriate, valid test instruments consistent with objectives.
18. Correlates bulletin board with current curriculum or seasonal topics.

Knowledge of Subject Matter

The degree to which the teacher:

1. Answers questions knowledgeably.
2. Is able to elaborate.
3. Displays depth in knowledge of subject matter.
4. Is able to use alternate approaches to convey concepts.
5. Researches concept-related questions.

Planning

The degree to which the teacher's plans and/or teacher's implementation of plans exhibit:

1. Adherence to curriculum guide.
2. Clearness of objectives.
3. Identification of concepts to be presented.
4. Appropriate activities.
5. Sequence of presentation.
6. Motivational techniques.
7. Individualization, when applicable.
8. Materials.

Other characteristics looked for by a supervisor or administrator:

1. ***Teaching Personality***

   Poise, tact, sense of humor, likableness, enthusiasm.

2. ***Native Ability***

   General intelligence, judgement, and adaptability.

3. ***Emotional Stability***

   Even disposition, mature control, temperamentally fitted to teach.

4. ***Ability to Instruct***

   Choice of material, daily preparation, procedures.

5. ***Relationship with Pupils***

   Interest in and understanding of needs of individuals, pupil cooperation, and participation.

6. ***Voice and Speech***

   Pleasing quality, well-modulated, distinct, clear.

7. ***Poise***

   Recognizing problems that will go away and those which will have a rippling effect. Emotional control.

8. ***Classroom Environment***

   Lighting, attractiveness.

9. ***Classroom Management***

   Students under control.

10. ***Leadership***

    Ability to inspire pupils, ability to delegate responsibility to pupils successfully, initiative, self-reliance, and tact. Flexible.

Appendix VI

PROFESSIONAL ASSISTANCE SCHEDULE

SESSION 19____ -19_____

EVALUATEE:____________________ POSITION:____________________

EVALUATOR:____________________ POSITION:____________________

DEPARTMENT/SCHOOL:____

DATE ISSUED:________________ CONCLUSION DATE:________________

ASSISTANCE: *(Check One)* ☐ LEVEL I ☐ LEVEL II

I. Performance Area(s) Requiring assistance:

____

____

____

II. Activities (Activities will be verified on Log of Professional Participation):

	Beginning Date	Completion Date
(1)		
(2)		
(3)		

III. COMMENTS:

____

____

____

____

I have read and received a copy of this form. Signature does not imply agreement or disagreement with content.

__________________________ __________________________

EVALUATOR DATE EVALUATEE DATE

Interviewing for Excellence: A Guide to Teacher Characteristics 19

ARTHUR E. LEBOFSKY
CLARKSTOWN SOUTH HIGH SCHOOL

KATHLEEN P. RANWEZ
JEFFERSON COUNTY, COLORADO SCHOOL DISTRICT

LARRY G. CLARK
TOLEDO HIGH SCHOOL

ANNA CLAIR CODNER
WEATHERFORD, OKLAHOMA

The personal interview is a crucial factor in hiring new personnel. This function of supervision has become more important with the effects of increasing mandates, teacher retirements, and staff defections. Yet educational leaders rarely have the time to synthesize existing research data and develop an easily applied model which can assist in hiring the best available talent.

The research base needed to support a more valid interview process does exist. The 1982 Search for Excellence in Science Education (SESE), sponsored by the National Science Teachers Association and funded by the National Science Foundation (NSF), identified 50 exemplary science programs that met specific criteria. These criteria were originally developed as part of the NSF Project Synthesis, a random, stratified national survey of administrators, supervisors, teachers, and other school personnel. A crucial follow-up to the original process was the construction of a profile of an exemplary teacher. As R. J. Bonnstetter affirmed, "Describing characteristics of key teachers of exemplary programs represents a major component which must be documented if we ever hope to provide a path to excellence in science education" (Bonnstetter et al., 1983).

With the descriptive data now available (Weiss, 1978; Bonnstetter, 1983; Penick, 1984), some conclusions about the characterstics of an exemplary science teacher can be drawn. One could also extrapolate how the better teacher candidate would respond to various interview questions. The literature identifies 12 teacher characteristics common to teachers in recognized exemplary programs. These teachers

- have a defensible vision of the ideal teaching and learning environment
- see teaching as a dynamic, multivariate activity
- know that ideas, materials, and curricula must change
- are proactive rather than reactive
- work and communicate well with others
- are confident they can succeed and have a high tolerance for risk
- have had experience with hands-on materials

- have worked with children of all age levels
- understand the content and methods of their field of science
- are models of active inquiry, equating teaching with learning
- have the creativity and energy necessary to create and implement a challenging science program
- are professional and up-to-date in their teaching methods and science content

The Questions to Be Asked

If one accepts the cluster of these characteristics as an indication of exemplary science teaching, then a supervisor or administrator should be able to identify such a prospect from a selection of candidates. Questions keyed to the characteristics could be developed to elicit selected responses that would either indicate prior exemplary behavior or predict future development and success.

With this charge, the following questions were created and the responses of an ideal candidate hypothesized. These questions can be posed to the candidate in an interview, and the responses compared to those generated by the SESE sample. Two major caveats, however, must be considered. First, this should not be used as the sole determinant of prior success or future potential: An administrator concerned about hiring the best possible staff member should use several interview techniques, including but not limited to the methods outlined here. Second, these questions should not be used as an evaluative, judgmental methodology for those currently employed. That would be an invalid use of the data collected in the original research. The following categories are a guide to a selection of questions, developed to assist the administrator hiring a science instructor. While the projected responses are those of a hypothetical exemplary teacher, a continuum could be considered in ranking the appropriateness of any given response.

The Interview

Question: Have you been active in the professional organizations of science educators?

Organizations that may be mentioned include the National Science Teachers Association, the state Science Teachers Association, National Association of Biology Teachers, National Earth Science Teachers Association, American Association of Physics Teachers, and the American Chemical Society.

Question: How active have you been in the organization?

The exemplary teacher has participated in conferences, has been a presenter at conferences, has been an officer in the organization, or has written for the organization's publications.

Question: What science-oriented journals, magazines or newsletters do you read regularly?

Among those that may be mentioned include *The Science Teacher, Discover, Popular Science, Science and Children, Scientific American, Science News, American Journal of Physics, School Science and Mathematics, The American Biology Teacher, The Earth Scientist, The Journal of Chem Ed, Physics Today, The Physics Teacher*, and their state science association's magazine or newsletter.

Question: What have you done to continue to grow professionally and personally?

Exemplary teachers regularly attend local workshops and inservice activities and have frequently attended regional or national conference sessions. Moreover, the teacher will make a regular attempt to take more formal college courses and may have broad travel experiences.

Question: In what committee activities have you been involved in your school experience?

Most commonly mentioned by exemplary

teachers were group activities such as task forces, staff relations, and curriculum development.

Question: How are you involved within your community?

Exemplary teachers have a broad base of community involvement—scouting, coaching, volunteer work, church work, service organizations, parent-teacher associations, and political organizations.

Question: What do you consider to be an ideal teaching environment?

Based on the research, a specific set of indicators is characteristic of the class environment and philosophy of exemplary teachers. As viewed by such staff, the ideal environment includes

- teacher/student enthusiasm
- student-centered activities
- an inquiry approach to teaching
- less teacher demonstrations, more student use of manipulative and/or hands-on materials
- less lecturing and more discussion than the norm
- use of televised and computer-assisted instruction in classes
- extensive use of off-site activities, outside resources, and guest speakers
- culture of living plants and/or animals in the classroom
- a class atmosphere that is both stimulating and accepting

Question: What are your attitudes about change and what part have you played in promoting change?

Exemplary teachers are receptive to change and help to promote it. They are continually open to new ideas as indicated by their attendance at NSF Institutes, conventions, workshops, and inservice activities. They consider change an opportunity for growth.

Question: How do you respond when confronted with difficult decisions?

The teachers should demonstrate flexibility in their use of time, schedule, curriculum, and in their view of themselves. Flexibility in the face of adversity is a key characteristic of an exemplary teacher.

Using Local Criteria

Administrators should certainly consider local criteria along with the more general concepts outlined above. A selected student committee could develop a list of characteristics they would consider common to exemplary teachers (see, for example, Yager and Bonnstetter, 1984). Teachers, administrative staff, lunchroom/custodial personnel, and parents could also be involved in developing this criteria list. These diverse populations, responding to a request for the characteristics of an exemplary teacher, provide an additional local source of questions and anticipated responses in the assessment process.

In addition to these questions and criteria lists, it is strongly recommended that peer observations be included in the process. An instrument developed by the science staff should include observational measures of creativity, management skills, and communications skills. A teacher from the department may also be included in the interviewing of new candidates. These methods can enhance the interviewing skills of the departmental leader and principal in the ongoing search for excellence in education.

References

Bonnstetter, R. J., Penick, J. E., & Yager, R. E. (1983). *Teachers in exemplary programs: How do they compare?* Washington, DC: National Science Teachers Association.

National Commission on Excellence in Education. (April, 1983). *A nation at risk: The imperative for educational reform.* Washington, DC: U.S. Department of Education.

Penick, J. E., & Meinhard-Pellens, R. (Eds). (1984). *Focus on excellence: Science/technology/society.* Washington, DC: National Science Teachers Association.

Weiss, I. (1978). *Report of the 1977 national survey of science, mathematics, and social studies education teachers.* Washington, DC: National Science Foundation.

Yager, R. E., & Bonnstetter, R. J. (1984, May–June). Student perceptions of science teachers, classes, and course content. *School Science and Mathematics, 84*(5), 406–414.

Arthur Lebofsky is a science department chairperson who has given workshops internationally on observational methodology and STS education. He has been a supervisor for 15 years in the New York City suburbs and teaches interdisciplinary science courses.

Kathleen P. Ranwez is a teacher on special assignment for the Jefferson County, Colorado School District. Usually a junior high school science teacher, she is currently working on a revision of the district's seventh grade life science program.

Larry G. Clark is a high school science teacher in Toledo, Orgeon. He received special recognition for the solar home his pupils designed and built as part of his science program.

Anna Clair Codner is currently completing her pharmacy degree at Southwest Oklahoma State University. She taught physical science at the middle school level for 15 years in Silver Creek and Columbus, Nebraska, and was a Cooper Foundation award winner in 1983 for excellence in science teaching.

The authors are teachers in programs named as exemplary by the National Science Teachers Association's Search for Excellence in Science Education, and participated in the honors workshop for science teachers at the University of Iowa, June, 1984.

The Supervisor's Role in an Age of Growing Professional Autonomy Among Teachers

20

JERRY B. DAVIS
HOFSTRA UNIVERSITY

The American Federation of Teachers' Task Force on the Future of Education stated that the full professionalization of teaching and the restructuring of public schools to promote student learning should be major aims of the current educational reform movement. It also recommended that decisions about professional matters such as instructional strategies, staff development, and curricular materials should be the responsibility of teachers ("Second Stage Education," 1986).

In its *A Nation Prepared: Teachers for the 21st Century,* the Task Force on Teaching as a Profession, assembled by the Carnegie Forum on Education and the Economy, has become one of the strongest proponents of the professionalization of teaching. This task force has taken educational reform proposals further than previous reports: from the very beginning, it has advocated that teachers be given the autonomy that is the hallmark of professional work (*The 1984–86 Report of the Officers of the American Federation of Teachers,* 1986).

Teachers as Professionals

In writing about the importance of the professionalization of teaching, Albert Shanker (1985) stated that unless teachers move from collective bargaining to professionalism, they will fail in their major objectives, which include the preservation of public education in this country. He wrote that teachers are far from being professionals as many of us understand that term. He defined a professional as an expert who is allowed to operate fairly independently. Denemark (1985) wrote that "while asking for more professional behavior from teachers, some citizens and legislators have advocated controls over teaching that effectively block professional development" (p. 47). DeYoung (1980) stated that professionalism is based on autonomy, and educational bureaucracies will not give up their power over teachers. Alma Wittlen (1965) wrote that teachers in the American classroom have very limited power of decision making. She cited a survey which showed that the lack of democratic administrative procedures and the lack of a share in policy-making were among the main causes of poor teacher morale.

Shanker (1987) pointed out that many of the recent books on achieving excellence in business call for greater participation of employees in decision-making processes. However, he noted that middle management is often the source of opposition to employee participation.

If employees are no longer...told what to do but are now given the responsibility for planning, executing and evaluating their work, it's not surprising to find that the old foreman...believes that a new scheme just won't work unless he's on top of it all—unless he's supervising it. Also, there's fear that, in a system that involves all employees fully, there may be no role, or a much smaller one, for management. Middle managers feel there'll be a loss of numbers, status, and power. (p. 5)

Shanker says that similar reactions are beginning to appear in some school systems where teachers are asking for greater responsibilities. He cites, as a case in point, the school principals in Rochester, New York, who went to court to deny State funds for a mentor-teacher program where experienced teachers provided assistance to their colleagues. Thus we find forces within the educational system itself that work against the expansion of teachers' professional power.

What alternatives do supervisors have in responding to the move to extend and expand professional autonomy among teachers? One, of course, is to fight against it. If supervisors view the expansion as an invasion of their role and responsibilities and thus feel threatened, then obstructive behavior may be the reaction. On the other hand, if supervisors support the movement to professionalize teaching, then an examination of the supervisor's role in facilitating greater professional autonomy among teachers is in order. If the latter is chosen, what will the supervisory role be like? The purpose of this article is to answer that question and to show that the supervisor's position may be strengthened as teachers assume greater professional autonomy.

Underlying Assumptions

Before describing a supervisory approach and a series of supervisory activities designed to increase teachers' professional autonomy, some underlying assumptions need to be made explicit. The assumptions are as follows:

- Teachers are professionals and will behave as such when dealt with accordingly.
- Teachers, like all professionals, want to improve their professional performance.
- Teachers are capable of setting directions designed to improve their performance themselves.
- Decisions made by teachers to improve their performance will lead to more enduring changes than decisions imposed by others (supervisors).
- A trusting, collegial relationship between a supervisor and a teacher is more conducive to the professional growth of both and provides greater support for professional endeavors than the traditional supervisor-teacher relationship.
- A relationship in which teachers interact with one another in a professional, trusting, collegial manner is more conducive to professional growth and provides greater support for professional endeavors than when teachers are isolated from one another.

No singular supervisory activity described below, in and of itself, will have sufficient impact to bring about marked professional autonomy among teachers. The implementation of many activities may make a difference. By taking the supervisory approach outlined here and including many such activities within one's approach, supervisors may facilitate professional autonomy among teachers and foster the professionalization of teaching. In addition, they may also strengthen their own position as leaders within a community of professionals.

Intervisitation Among Colleagues

Supervisors who teach part of the day can encourage teachers to visit their classrooms to observe their teaching performance. Some supervisors do, on occasion, invite teachers into their classrooms, but it is usually for a specific purpose, such as to observe a certain technique. Rarely do supervisors establish an open classroom door policy and genuinely encourage teachers to visit. However, by doing so, supervisors nonverbally express to teachers, "I am your colleague. I am exposing myself as you are exposed when I visit your classes to observe your teaching performance." This may be the first step toward a collegial relationship. The supervisor [illegible] clarify that the intent is not to demonstrate what he or she would like the teacher to do. The opportunity to observe should come with no strings attached and should be entirely without imposition. The observation may lead to discussion. Ideas may be exchanged. The teacher, in turn, may adopt or adapt something he or she has observed or modify something he or she is doing. Such decisions, though, must be solely those of the teacher. In turn, the supervisor might also decide to make some changes in his or her approach to teaching.

The outcome may be greater than this. As the teacher and the supervisor each make decisions about his or her own teaching performance, steps toward increasing professional autonomy are also being taken: A professional, trusting, collegial relationship between the teacher and the supervisor. never before so experienced by either, may begin to develop.

In establishing the practice of having teachers observe one's teaching performance and developing a trusting, collegial relationship with them, a supervisor might encourage the teachers within the department to do likewise. The trust and collegiality developed between supervisor and teacher may serve as a model for the kind of relationship teachers might develop among themselves.

Rarely do teachers observe their colleagues' teaching performance. Most teachers are reluctant to expose themselves. In addition, the very nature of our educational system tends to reinforce the isolation of teachers. By trusting one's colleagues and having some positive experiences of a collegial nature, teachers may choose to move out of isolation. Teachers have much to gain by visiting one another and sharing ideas. Intervisitation might lead not only to improved teaching performance but also to decisions to enter into cooperative arrangements, such as collaborative planning and team teaching. Thus the walls isolating teachers may begin to crumble.

To take this one step further, teachers might be encouraged to visit one another across department lines. Some areas of common concern transcend the various subjects, such as classroom management and control, teaching techniques, and principles of learning. In addition to outcomes similar to those that occur when teachers visit supervisors and the other teachers within their department, intervisitation across department line may lead to the sharing of novel ideas, working together to correlate learning outcomes, and interdisciplinary team teaching. Such arrangements of course, should be the outgrowth of decisions made by teachers.

Systems of Analysis

Another supervisory practice that may contribute toward increasing professional autonomy is to encourage teachers to explore systems designed to analyze the interaction in their classrooms. This can be done during department meetings or on a one-to-one basis. By learning what goes on in their classrooms, teachers can then make some decisions of a self-directing nature.

If teachers are interested in learning about the kinds of thinking the questions they ask in class provoke, the Aschner-Gallagher system might be presented to them. Aschner and Gallagher (1963) based their system upon the work of J.G. Guilford (1956). This system has four broad categories of questions: cognitive memory, convergent, divergent, and evaluative.

Cognitive memory questions require nothing more than recalling information. Some examples: What do the letters DNA represent? Who discovered the nucleus of the cell? What is the Law of Universal Gravitation?

Convergent questions call for the analysis and integration of remembered knowledge. They require reasoning to reach an answer. Some examples: How would things be different if the earth's axis were perpendicular to the plane of the earth's orbit? If the force between two bodies is equal to the product of the masses of the two bodies divided by the square of the distance between them, what would happen to the force between two bodies if the distance between them were doubled?

Divergent questions require imaginative and creative thinking. One often has to manipulate data to answer such questions. There is not one and only one correct answer to such a question. An example of a divergent question is: How would living be different in a society in which all diseases had been conquered?

Evaluative questions call for matters of judgment, opinion, value, and choice. Examples: What criteria would you apply to determine who were to receive human organ transplants if there were more people who needed them than there were organs available? What do you believe should be done to or for people who carry genes for serious birth defects?

Once a teacher has learned to classify questions into these four categories, he or she can tape-record his or her lessons, listen to the tapes, and count how many questions of each type have been asked. The teacher can then determine the percentage of each type of question asked. For example, if 21 out of 28 questions asked during a lesson were cognitive memory, then 75 percent of the questions required students only to recall what they knew. If a teacher then decides that he or she wants to ask questions that call for other kinds of thinking more often, he or she can formulate key questions of those sorts when planning lessons. A supervisor can help the teacher in the above process by observing and recording data and guiding the teacher in interpretation and analysis.

Social-Emotional Climate

If teachers are interested in obtaining knowledge about the social-emotional climate of their classrooms, then information about the use of a system such as Flanders can be helpful (Amidon and Flanders, 1967). This system will help answer such questions as: Do I accept students' feelings? How much time do I spend praising and encouraging students? Is my praise brief or sustained? Do I build on students' ideas? How often after asking questions is there at least a three-second pause before students answer? How much time do I spend lecturing? How much talking do I do during a lesson? How often during the lesson do students initiate what they say? How much time do I spend criticizing students?

This system has 10 categories of verbal behavior. The first seven involve "teacher talk": accepts feelings, praises, accepts or uses students' ideas, asks questions, lectures, gives directions, and criticizes. The next two categories involve student talk—student responses solicited by the teacher and student talk initiated by the student. The tenth category is silence or confusion.

This system requires a teacher to either tape-record his or her lesson or invite an observer into the classroom to record, in number form, each verbal behavior as it occurs every three seconds. Each category is assigned a particular number for coding purposes. One must learn some ground rules in order to properly code the behaviors. After coding, the data is placed into a matrix which, when analyzed, provides the teacher with much information about the verbal interaction in his or her classroom. The teacher can then make some decisions about the patterns he or she employs.

Teachers can use many other systems to record and analyze the interaction in their classrooms. One should select a system that contains categories of behavior that will provide the kind of information the teacher seeks.

Supervisors need to be knowledgeable of various systems and sources of information about them (Simon and Boyer, 1967).

Clinical Supervision

Another means of promoting professional autonomy is for supervisors to employ a clinical supervisory approach in their work with teachers. Smyth (1984) says that the kind of supervisory approach most likely to provide benefit is one which enables teachers to experience autonomous professional development through the systematic study of their own teaching. He writes that clinical supervision should not be viewed as a method for improving teaching, but as a means of empowerment by which teachers can gain control over their own teaching and, in turn, their development as professionals.

A clinical supervisory approach is thoroughly presented by Goldhammer (1969). This approach, with modifications that I believe would be in line with Smyth's position, may be briefly described as follows.

A supervisor who employs a clinical supervisory approach begins by first holding a preobservation conference with the teacher he or she is going to observe. The purpose of the pre-observation conference is for the teacher to provide the supervisor with information regarding the nature of the class, objectives, lessons, and so on. Other purposes of the preobservation conference include the development of trust and the alleviation of anxiety. In addition, it is at this meeting that the supervisor ascertains from the teacher those aspects of performance with which the teacher would like some help, assists in selecting or devising some means for improving his or her teaching, and agrees upon the means to be employed by the teacher or supervisor to obtain and record data of the teacher's performance. The goal of the pre-observation conference is to foster professional autonomy.

During the observation, the data-gathering method agreed upon by the teacher and the supervisor is employed. This may include audio or videotape recording by the teacher of his or her own performance. It may also include the supervisor serving as the recorder of observations. The supervisor might use an classroom observation instrument that was agreed upon or might record verbatim interactions or occurrences relating to those areas of interest or concern to the teacher.

Following the observation, the supervisor may engage in a preliminary analysis of the data, determine the patterns that characterize the teacher's performance, consider the teacher, and decide upon an approach for the post-observation conference. More desirable, though, would be for the supervisor to assist the teacher to analyze the data and determine the patterns that characterize the teacher's own performance.

During the post-observation conference, the recorded data is presented to the teacher for his or her analysis. The supervisor may guide the teacher so that all patterns which relate to those areas in which the teacher is interested are identified and analyzed. The supervisor may also guide the teacher to consider alternative patterns. Decisions to continue, alter, or replace patterns remain with the teacher. During the post-observation conference, the teacher may also seek the supervisor's help in devising strategies for implementing any changes he or she has decided upon.

After the post-observation conference, the supervisor looks back and analyzes his or her own performance at the post-observation conference and makes plans for working with the teacher in the future.

The conventional clinical supervisory approach can certainly be modified to lead to a truly collegial relationship between supervisor and teachers, with increasing opportunities to expand professional autonomy among teachers.

Teachers as Decision Makers

Another supervisory practice which by its very nature fosters professional autonomy is to involve teachers in decision-making matters. Teachers can be invited to examine and recommend textbooks and other curricular materials, submit topics to be discussed at department meetings, revise existing courses, propose and design new courses, identify their own professional needs, and devise plans for inservice education. People involved in making decisions usually have a greater feeling of ownership. They often work diligently in implementing the decision so that it will turn out to be successful. Although involvement in decision-making processes often requires a greater commitment of time and effort, there are incentives that encourage such participation. These include the fact that it is more desirable to participate in decisions than to leave them to others (supervisors), especially if implementation becomes the responsibility of the teachers. The strong support teachers may receive from supervisors and administrators in the implementation of decisions made by the teachers themselves may also serve as a strong incentive.

Group Dynamics

To help facilitate the work of teachers when they come together in groups, supervisors should make mental notes of the dynamics of those groups, including those in which the supervisors serve. One of the supervisor's functions should be to help each teacher become a productive participant. A group's dynamics include the forces within the group that determine its behavior and the behavior of its members. Every group has its own forces. The conditions shaping such forces include the degree of acceptance and trust members share, the underlying animosities that may exist, the relative status each member is perceived to have, and so on. Supervisors need to understand those conditions and forces that exist within groups as well as the basic principles that underlie effective group relations. With this knowledge, they need to function and to help others function in ways which lead to the success of groups.

It is essential that supervisors be process oriented. They need to encourage participation of all group members; help develop trust; facilitate communication; arbitrate whenever appropriate; seek and provide information, ideas, and opinions; and define positions. They need to help teachers learn to do the same.

The role of the supervisor described in this article is actually the role of a leader within a community of professionals. The approach and practices described are intended to be helpful to supervisors in guiding teachers toward greater professional autonomy. When teachers, with the help of supervisors, set the direction for their own improvement, obtain feedback, analyze their own teaching, design strategies to improve their performance, become involved in professional decision-making processes, and relate to their supervisors and to one another on a collegial basis, supervision may be regarded in a favorable light.

References

Amidon, E.J., & Flanders, N.A. (1967). *The role of the teacher in the classroom.* Minneapolis: Association for Productive Teaching, Inc.

Denemark, G. (1965). Educating a profession. *Journal of Teacher Education, 36*(5), 46–52.

De Young, A.J. (1980). Professionalism and politics: Toward a more relistic assessment of the issue. *The Clearing House, 53*(6), 268–70.

Gallagher, J.,& Aschner, M.J. (1963). A preliminary report: Analysis of classroom interaction. *Merrill-Palmer Quarterly of Behavior and Development, 9,* 183–194.

Goldhammer, R. (1969). *Clinical supervision.* New York: Holt, Rinehart & Winston.

Guilford, J.P. (1956). The structure of intellect. *Psychological Bulletin, 53,* 267–293.

The 1984–86 report of the officers of the American Federation of Teachers. (1986). *American Teacher, 71*(1), 5–17.

Second stage education reform needed, AFT task force says. (1986, June 23). *New York Teacher,* p. 3.

Shanker, A. (1985). In support of teachers: The making of a profession. *Bulletin of the National Association of Secondary School Principals, 69* (482), 93–99.

Shanker, A. (1987). Teachers as school leaders. *American Teacher, 71*(6), p. 5.

Simon, A., & Boyer, E.G. (Eds.). (1967). *Mirrors for Behavior.* Philadelphia: Research for Better Schools, Inc.

Smyth, W. J. (1984). Toward a critical consciousness in the instructional supervision of experienced teachers. *Curriculum Inquiry, 14,* 425–436.

Wittlen, A.S. (1965). The teacher. In K. Lynn (Ed.), *The professions in America.* (pp. 91–109). Boston: Houghton Mifflin.

Jerry B. Davis is Professor of Secondary Education at Hofstra University in Hempstead, New York. He is the author of over 25 articles on science education, supervision, and teacher education. He has served as an executive board member and president of Nassau County Science Supervisors Association. He has also served as curriculum consultant in science for the City University of New York's College Discovery and Development progam, policy board member of a Teacher Center, program development specialist of a Teacher Core program, and director of NSF-supported inservice institutes in BSCS biology at Hofstra University.

What Does Research Say to the Science Supervisor?

What the Science Education Literature Says About Elementary School Science

21

ANN TOWSLEY
BURTON E. VOSS
UNIVERSITY OF MICHIGAN

The science supervisor with no elementary teaching experience may be on unfamiliar ground when faced with the task of improving elementary science teaching in his or her district. He or she may be surprised to discover that science, a relatively stable part of the curriculum in postelementary education, may be considered a frill in the elementary curriculum by teachers, administrators, and community alike. Even if time and money are allocated for science, the supervisor may be further stonewalled by negative teacher attitudes. Teachers may skip over or skim teaching science because they dislike the subject or feel inadequately trained. Perhaps some teachers do teach science, but stick to a single textbook and squeeze instruction in at the end of the school day. Some of these teachers feel that sufficient science for young children is the study of vocabulary and memorization of terms—a concept of science teaching that the supervisor with secondary or intermediate teaching experience is probably familiar with.

This chapter first addresses the status of elementary science as described by the three 1977–78 NSF status studies and the 1978 Science Assessment of the National Assessment of Educational Progress. The second half describes what the literature says about the value of science in the elementary school and how these findings may help the supervisor stimulate teachers to improve elementary science.

Each supervisor has a unique list of problems which may or may not reflect the situation described above. There are many excellent elementary science teachers, and some have been identified by the NSTA Search for Excellence in Science Education (Education USA Report, 1983).

The Status of Elementary Science Teaching

The picture above describes the typical elementary classroom as disclosed by three NSF studies in 1977 and the 1978 National Assessment of Educational Progress. These were comprehensive studies, covering many classrooms and districts nationwide and undertaken to assess the status of science, mathematics, and social studies education in the United

States. These studies included

- a search of published and unpublished literature covering the period 1957–1975 by Hegelson and others at Ohio State (Helgeson, Blosser, and Howe, 1977)
- a nationwide questionnaire survey of science educators, administrators, teachers, and supervisors headed by Weiss at the Research Triangle Institute (Weiss, 1978)
- eleven in-depth case studies of schools undertaken by Stake and Easley at the University of Illinois (Stake and Easley, 1978)
- achievement and attitude data collected from students in the NAEP 1978 study

The data from these studies has been cited, summarized, and analyzed numerous times by science educators (see, for instance, *What Research Says to the Science Teacher* [Harms and Yager, 1981] and *What are the Needs in Precollege Science, Mathematics and Social Science Education? Views from the Field* [National Science Foundation, 1980].) The picture of elementary science teaching that emerges from these studies is clear—time and money for elementary science are in short supply and activities-based science in the classroom is rare.

Status of Time Spent on Elementary School Science

Teacher-reported time, allocated time, and observed time for science differ from study to study. Twenty-five percent of the states and 40 percent of the school districts in the nation set guidelines for the minimum amount of time to be spent on each subject. Of these, the average recommended minimum time for science was 30 minutes per day in grades K–3 and up to 40 minutes per day in grades 4–6 (Weiss, cited in Panel on School Science Commission on Human Resources of the National Academy of Sciences, National Research Council, 1980).

The average teacher-reported time was considerably less. K–3 grade teachers reported that, per day, they spent about 20 minutes on science, compared to 20 minutes on social studies, 40 minutes on mathematics, and 95 minutes on reading. Teachers of grades 4–6 reported they spent about 30 minutes on science, compared to 35 minutes on social studies, 50 minutes on mathematics, and 65 minutes on reading (ibid.). Mechling and Oliver (1982) observed that a 1980 NSF survey uncovered even lower average times: 17 minutes for science in K–3 and 28 minutes in 4–6. Even more pessimistic estimates were given by Sigda (1983): "...in the elementary school, the average child will spend less than one out of 25 instructional hours per week studying science" (p. 625); and Rutherford, "at the elementary school level, instruction in science has almost ceased, being no more in most cases than a few minutes each week of reading from textbooks" (cited in Mechling and Oliver, 1983c, pp. 2–3).

Status of Financial Support for Elementary School Science

The studies indicated that by the late 1970s there was "near universal agreement that school dollars for science are declining" (Pratt, 1981, p. 88). Although 40 percent of schools required instruction in science, a budget for science materials was listed in only 16 percent of the schools (ibid.). Across all grade levels teachers themselves perceived financial issues to be the major focus of difficulty: "Teachers considered inadequate facilities, insufficient funds for purchasing equipment and supplies, and lack of materials for individualized instruction as the three most serious problems affecting science instruction" (DeRose, Lockard, and Paldy, 1980, p. 48). Of the funds elementary schools do have at their disposal, only a small proportion was budgeted for curriculum materials in the first place and science "usually fares badly in the competition for scarce funds" (ibid. p. 45).

Status of Activities-Based Science

An activities-based science program incorporates demonstrations, hands-on activities, discovery, and/or inquiry methods in place of or in addition to a single textbook program. These programs may be many and various, from teacher developed curricula to one of the NSF-developed programs, such as SAPA, ESS, or SCIS. Although "discovery" and "inquiry" imply student-initiated investigation and the development of process and problem-solving skills, "activities-based" also includes teacher demonstrations, isolated verification labs, and hands-on activities as motivators. Activities in the former are apt to be tied together in a more systematic and developmental way than the latter. "Activities-based" science actively engages students with materials or equipment as a regular part of their science program.

At the time of the Weiss survey, 31 percent of the elementary school districts reported using one of the activities-based NSF programs. Teachers reported that, when they taught science, 46 percent of K–3 and 56 percent of grades 4–6 teachers used a single textbook program (Pratt, 1981). Were these single textbook programs based or supplemented by activities? Only one in three elementary classrooms was reported to use hands-on experiences once a week or more (DeRose, Lockard, and Paldy, 1980). "Elementary school science, like that in junior and senior high schools, is taught primarily by lecture and recitation based on one textbook" (ibid. p. 45).

Survey data suggest that the domination of the curriculum by the textbook tends to discourage use of inquiry techniques which require students to do more than look up information in the text and then recite or record it. In addition to reading and recitation, teachers report that workbook exercises provide much of whatever activity exists in typical classrooms. (ibid. p. 44)

Behind the Status of Elementary Science: Value and Teacher Competence

Is more time and money a sufficient guarantee of good elementary science instruction? What are the reasons for this state of affairs in the elementary school? Why does science appear to be, in the words of Mechling and Oliver (1982), the "stepchild of the elementary curriculum?" There are already many demands on the elementary school day: teachers could well lament that *no* curriculum subject gets the full time and attention needed to teach it well and money is tight all over. But in some elementary classrooms science is an exciting and dynamic part of the curriculum, as evidenced by NSTA's identified exemplary science programs (Penick, 1988). Why do some teachers have the time and facilities to make science a vital part of their curriculum and others do not? Do they have more time or do they make more time? It is true that the NSTA exemplary science program teachers were less likely to cite inadequate facilities as a serious problem. They were more likely, in fact, to rate their facilities, supplies, funds, space, and assistance as very good or satisfactory compared to other science teachers' ratings of the same (*Education USA*, May 30, 1983).

Is it simply that more time and more money will lead to better elementary science education? This may be the case in those districts where eager, science-minded elementary teachers have been frustrated in their attempts to teach science with bare science cupboards, or shortened school days, or pressure from standardized achievement tests that include no science. But in many cases the studies indicate that behind the lack of time and money a more subtle obstruction exists: attitude toward elementary school science. Elementary school science may not be seen as either valuable or necessary. Teachers who don't like science or feel inadequately trained may either skip or skim it in the classroom in spite of allocated time. Administrators and parents who regard elementary science as a frill are unlikely to allocate it time and money in the first place.

Analysis of the NSF studies indicates that science education and activities-based science are a low priority compared to other parts of the elementary curriculum, and that many teachers feel inadequately trained to teach science.

What the Studies Say About Elementary Science as a Low Priority

State boards of education rarely consider knowledge of science to be basic, and science education is rarely included in state needs assessments (DeRose, Lockard, and Paldy, 1980). Stake and Easley report that, while elementary principals believe that science is a basic, the three R's should be taught first (Pratt, 1981). In addition, teachers of older students may dampen elementary science enthusiasm: Junior and senior high school teachers felt that perhaps science was not very important in the elementary school (Smith, 1980).

Koballa and Bethel found that "...many people, including teachers, feel that science at the elementary level is a frivolous, superfluous subject and should be excluded from the instructional day" (1984, p. 79). It was also found that

> *...science in the elementary schools, not regarded as basic, is given a low priority in comparison to reading, mathematics, social studies, and health. Most elementary school teachers and, presumably, their school administrators see little relationship between science and other areas of the curriculum. (DeRose, Lockard, and Paldy, 1980, p. 45)*

What the Studies Say About the Priority of Inquiry Science

We can conclude that, in some districts, elementary school science education is not considered valuable. How do inquiry methods rate? The following is a list of conclusions drawn from Helgeson's and Stake and Easley's reports. These conclusions relate specifically to inquiry methods, rather than the broader "activities-based" methods, and include comments from both elementary and secondary teachers:

- Teachers find inquiry approaches difficult to manage.

- Some consider inquiry dangerous, especially in discipline problem classrooms.

- Inquiry is perceived as not working for most students.

- Inquiry is perceived as causing confusion and too difficult for any but the very brightest students.

- Many teachers and parents consider the primary purpose of science education to be preparation for the next level of schooling: this means content, not process, skills.

- "Socialization" (training students to follow directions, pay attention, do homework, and take tests) of students leads to activities stressing authority and discipline: for many teachers, inquiry teaching is inconsistent with these activities (Welch, 1981).

Teachers are not adverse to the *goals* of inquiry teaching. Indeed, teachers and principals rank information-processing and decision-making skills as very important and generally value first-hand learning (Welch, 1981). Teachers made positive statements about the value of inquiry, but they often felt more responsible for teaching facts (ibid.). The practitioners and curriculum developers seem to agree about the desired outcomes, but apparently disagree about what works to produce them. Or, although teachers may value the goals of inquiry, they may perceive the goal of fact retention to be more valuable.

What the Studies Say About Teacher Competence and Feelings of Inadequacy for Science Teaching

Elementary school science instruction ultimately rests with the teacher. There is evidence that teacher attitude plays a very important role in whether science is really taught in the classroom. "Weiss' survey showed that elementary teachers' perceptions about their qualifications for teaching science were consistent with the amount of time spent teaching it" (cited in Bethel, 1984, p. 152). Regarding elementary teachers' perceptions of their ability to teach specific subjects, Weiss found that, while 49 percent felt qualified in mathematics, and 39 percent felt qualified in social studies, only 22 percent felt qualified in science (op.cit.).

Hurd (cited in Bethel, 1984) found that 51 percent of elementary teachers say their preservice training did not prepare them sufficiently to teach the required science on a daily basis; 71 percent never had inservice science training. Elementary teachers were found to have negative or neutral attitudes toward science and tended to teach little or no science (Bethel, Ellis, and Barufaldi, 1982; Koballa and Bethel, 1984). Mechling and Oliver (1983b) report that a survey of elementary teachers in 12 states reveals that

- one half do not feel prepared to teach science
- the majority do not feel comfortable teaching physical science
- three out of four have never had inservice instruction in science

This feeling of inadequacy by elementary teachers to handle science instruction permeates all three studies [NSF status reports] and indicates a need for some serious work by all those who can help alleviate this problem. (DeRose, Lockard, and Paldy, 1980, p. 46)

The First Step: Making Elementary School Science Valuable and Elementary School Teachers Feel Qualified

It is clear that teachers and school communities that do not value science education in the first place are unlikely to include it in the elementary curriculum. The science supervisor battling for a share of the elementary school time and money budget would do well to address the issue of the value of elementary science instruction. Again, teachers who do not value science education and feel uncomfortable teaching it are unlikely to be motivated to make room for it in their busy day. Nor are they likely to be motivated to somehow surmount the difficulties of low science supplies by scrounging or making their own. And, although there may be general agreement about the goals of inquiry science in one's district, confusion may exist about the methods. The supervisor needs to address these issues of elementary school science. The first step the supervisor should take might be changing teacher and community attitudes toward elementary science. To do this, the supervisor must emphasize that the outcomes of science education are indeed valuable, and that the elementary classroom teacher is capable of good science instruction.

The following are pieces of relevant research or position statements that help address issues, queries, and comments the supervisor may run into in an effort to affect an attitude change. The issues, barriers, objections, or problems are stated at the head of each section and the response of both the research and the supervisor then follows.

Science is not one of the basics in back-to-basics.

Science and technology influence every aspect of our lives. They are central to our welfare as individuals and to the welfare of our society. All around us are examples of the importance of *science and technology for production of food, water, shelter, clothing, medicines, transportation, and various sources of energy. There are an increasing number of science and technology-related societal problems as well as increasing societal benefits. Science and technology are central to our personal and cultural welfare and to many societal problems. We must insure appropriate science education for all citizens. (NSTA Position Statement, 1982, p. 1)*

Robert Yager (1983a) and others have proposed that our goal as science educators is to create widespread science literacy instead of investing our energies in the 3 percent of high school graduates who go on to be future scientists and engineers. What is scientific literacy? It is an awareness of the processes and goals of science, a basic familiarity with the major content and issues in science and technology, and an awareness of the synergistic relation of society and science (see the NSTA Position Statement, 1982, or Koballa's [1984] chapter "Goals of Science Education" in *Research within Reach* for a more detailed treatment).

What does this mean for elementary school science? How can we expect young children to deal with and understand complicated and controversial societal issues, especially when they are incapable of understanding the relevant scientific concepts and processes in any sophisticated way?

A carefully planned and articulated elementary science curriculum should provide daily opportunities for the sequential development of basic physical and life science concepts, along with the development of science process and inquiry skills.

Elementary science would provide opportunities for nurturing children's natural curiosity. This helps them to develop confidence to question and seek answers based upon evidence and independent thinking. Children should be given an opportunity to explore and investigate their world using a hand-on approach, with instructional materials readily available.

The focus of the elementary science program should be on fostering in children an understanding of, an interest in, and an appreciation of the world in which they live. (NSTA Position Statement, 1982, p. 2)

Scientific literacy begins with showing children that science is something they have ready access to, can understand, can do, and can control. Children should become aware of the kinds of questions science can ask and try to answer, the mistakes and false starts we make in science and how we learn from them, how we contrive to correct our faulty experiments, the team work involved, the thrill of discovery. These are basic to understanding how science and scientists work in our everyday world.

If scientific literacy in our citizenry is a desirable goal, then science at the elementary level becomes basic for another reason: many children may well get all their science education prior to the 10th grade. According to Helgeson, et al., over 50 percent of the students enrolled in our schools at the time of the study (1978) were not required to take science beyond 10th grade biology. This makes good science instruction in grades K–9 particularly critical (cited in Bethel, 1984).

I can't squeeze another subject into my already too full day.

Would this be adding another demand on time, or is there a way that science can be integrated into math, social studies, and reading times for the benefit of all subjects? Ruth Wellman reviewed educational research and found evidence to support five generalizations:

- Active experience with science helps language and logic development.
- Science instruction appears especially helpful for children who are considered physically or culturally "different."
- Selected science activities accelerate reading readiness in young children.
- Science activities can provide a strong stimulus and a shared framework for converting experiences into language.
- Reading skills stem from language and logic

development which comes after concepts are formed from repeated encounters with objects and events. Such encounters are provided by science experiences. (Cited in ERIC, 1982.)

Koballa and Bethel, in *Research within Reach* (1984), reviewed studies of the effects of science experiences on achievement in other areas such as social studies, health, and fine arts. These studies indicate that science experience strongly affects transitions to the next level of cognitive development. Science experiences from SAPA and SCIS were shown to correlate with achievement in mathematical problem-solving and reasoning skills. In general, Koballa and Bethel found that the integration of science with other school subjects is mutually beneficial, and that this integration provides students with examples of the interdependence of knowledge.

In most of these studies at the elementary level, including those reviewed by Wellman (1978), science instruction was largely activities-based or inquiry-oriented. Science was not integrated into the reading curriculum by the simple expedient of having children read science: They worked with objects in an interaction setting. Their science was hands-on.

I thought we found out in the 1960s that inquiry didn't work. Besides, inquiry and activities-based programs are messy and require too much effort, time, and preparation. Kids are not really working, they're just messing around.

Shymansky, Kyle, and Alport (1983) synthesized the results of 105 experimental studies involving more than 45,000 students in which the new science curricula was compared to more traditional methods. They used the technique of meta-analysis to analyze the studies according to pre-selected outcome measures such as general achievement, analytic skills, process skills, and related skills (reading, mathematics, social studies, and communication), as well as attitude toward science. For elementary school science studies,

In all five performance areas where multiple studies were located, the effect size data indicate that students participating in the new programs performed significantly better than their traditional course counterparts. The performance of the average general science student in new science curricula exceeded 61–72 percent...of the students in traditional science courses for these five criterion clusters (p. 395–6).

For all 105 studies (including secondary school science), student attitude toward science was highly positive. The new science curricula also had strong positive effects in areas involving higher cognitive skills (critical thinking, problem solving, creativity, and logical thinking). The new science curricula were shown to relate positively to other curriculum areas such as reading, mathematics, and communication skills.

Ted Bredderman (1982) compiled the results of 60 studies of the effects of three activity-based science programs (ESS, SAPA and SCIS) when compared to classrooms using texts or other traditional ways of teaching science. These controlled studies involved 13,000 students in 1000 classrooms. The outcome measures included science process, science content, language development, creativity, attitude, and logic.

On the average the children in activity-based science programs performed 20 percentile units higher than did comparison students [for science process skills]...On tests of creativity, based on five studies, students in activity-based programs showed a benefit of about 16 percentile units. On tests of attitude, perception, logic, and language development the benefits of being in an activity-based program were about 10 percentile units; on measures of science content, about 5 percentile units; and math, about 5 percentile units. (pp. 39–40)

One surprising result was that academically or economically disadvantaged students gained more from the activity-based programs than did those students who were not disadvantaged. This was true on both science process and science content measures.

Perhaps when some teachers say that the

1960s curricula didn't work they mean that the curricula, *as designed*, didn't or wouldn't fit within the context of their teaching style or classroom. Did they find the expectations and intentions of some of the early curriculum developers too rigid or unrealistic for their own particular students and community? White and Tisher (1986) characterize a shift in the nature of science curriculum during the 1970s: The science teacher came to play a more dominant role, not only in the implementation of the curriculum, but in its development as well. This indicates a movement from the lock-step sequence and content of "teacher proof" curricula toward more flexible, less formal curricula adaptable to local conditions. Welch (1981), reacting to the data from the 1977–78 NSF studies, proposes also that the expectations of inquiry be reassessed at the local level. "We propose the more realistic view that not all students should be expected to attain competence in all inquiry outcomes. Such an expectation runs counter to what is known about student abilities and interest and ignores the influence of the school and community environment" (p. 53). Curriculum developers and science educators today expect science curricula to be adapted to the local classroom.

As stated previously, teachers and principals rank "information-processing and decision-making skills" as very important and generally value first-hand learning (Welch, 1981). This, coupled with the evidence of the beneficial outcomes of activity-based science, would lead one to conclude that activity based-science in the elementary school can be perceived as very valuable indeed. But it must be made *feasible* as well. Teachers will have to be convinced that it can work in the classrooms they currently have, and that the chosen science curriculum is flexible enough to fit their situation.

Developing the science curriculum to local classrooms requires teacher input: Teachers know the conditions in their classrooms and buildings. If a change is proposed, all participants should arrive at some essential understanding of that change. How is the class to be managed? How does one keep all children engaged and productive? How much whole group work, how much individualized study, how much small group work? Where and how will materials be assembled, prepared, collected, and stored? How much expertise does the teacher expect of her/himself? By the students of their teacher? What is a comfortable balance between content and process? Between deductive and inductive learning? In what way will teachers be accountable for the students' achievement? What will the achievement tests measure?

I'm going to need help if I'm going to teach science.

Only 40 percent of the elementary teachers in Weiss' survey felt that local inservice was useful (cited in Welch, 1981).

> *Teachers complain that inservice is irrelevant to the classroom; that inservice is too didactic; that inservice provides few opportunities to participate actively; that they have few or no opportunities for input during inservice planning; that there is a lack of continuous long-term inservice plan. (Bethel, 1984, p. 151)*

The NSF-funded inservices of the 1960s science curricula emphasized the latest developments in various science fields. They tended to pay little or no attention to instructional strategies or the teacher behaviors necessary for implementing the programs in the classroom (op. cit). More recently, however, research in curriculum has focused on the implementation aspect of curriculum development. For instance, in 1975 Klopfer and Champagne evaluated the Individualized Science program, describing its development, materials, and the shaping and implementation of the innovating strategies that would encourage teachers to use it (White and Tisher, 1986). Again, this reflects the trend away from getting the teachers to fit the program to designing the program to fit the teachers, the classroom, and the students.

Successful implementation of an innovation involves focusing on teacher reception and perception of the material. For elementary teachers who avoid teaching science, an innovation may be their first concrete introduction to the practical aspects of inquiry or hands-on science. A number of studies have shown that workshop experiences with inquiry methods and hands-on activities improve preservice teachers' attitudes toward science and inquiry methods (Bethel, 1984). Teachers appreciate the efficiency of such inservices: "Science teachers want inservice programs that are activity-oriented, practical, and tuned to their needs" (Mechling and Oliver, 1983a, p. 42).

An interesting note for supervisors is the following rating taken from Weiss' survey: Sixty-one percent of K–3 and 52 percent of 4–6 grade teachers found *other teachers* to be useful sources of information. Twenty-seven percent of K–3 and 21 percent of 4–6 grade teachers found *specialists* to be useful (Pratt, 1981). Other teachers are not only fellow experts in elementary teaching, they are also available to help in curriculum planning. The supervisor should enlist the help of some of these building experts for inservices.

Science makes me feel uncomfortable and unsure of myself. I feel inadequately qualified.

Yager and Bonnstetter (1984) reviewed the NAEP Third Assessment of Science (1978) and did a follow-up study in 1984 using the same questions that appeared on the national assessment. They asked 9 year-olds, 13 year-olds, 17 year-olds, and young adults about their perceptions of their science teachers, classes and course content. In both studies it was found that

Elementary school teachers are most successful with making science exciting. Perhaps their own lack of traditional science study, their own lack of understanding, their own wonderment and curiosity, their freedom in admitting their own lack of expertise is an advantage in making science personally exciting to students. It may be related to their greater encouragement of students to share ideas and experiences with others in the class. (p. 410)

How much of a science expert do you really have to be in order to teach science well? It seems probable that the more familiar the teacher is with the material to be taught, the more comfortable that teacher will be with teaching it. But this does not necessarily mean that the most effective science teachers are those with the most science in their backgrounds. Indeed, research "found that there was no correlation between formal subject-matter preparation and teacher knowledge of the subject or between formal subject-matter preparation and student cognitive learning" (Smith, 1980, p. 65). Perhaps there is a certain "threshold" amount of science teachers should know, beyond which other factors, such as enthusiasm or knowledge of child development, become the more effective components of good science teaching.

Koballa and Rice (1985) suggest that to improve attitudes toward science in the classroom, the teacher should project an image of credibility and have *sufficient* information, but should not be afraid to say, "I don't know." In addition, Bethel (1984) found evidence that, when teachers develop good science process teaching skills, knowledge of science was less important than actually participating in the design of inquiry lessons.

The science supervisor who lacks elementary teaching experience may face problems in improving science education unique to the elementary school situation. Elementary science may not be considered necessary or valuable and teachers may be reluctant to take on additional teaching subjects for which they feel inadequately prepared. Even if elementary science education is valued, teachers may feel that insufficient support, a tight classroom time schedule, and their own lack of science expertise are problems too large for them to surmount alone.

The science education literature offers the science supervisor material for convincing argument: The outcomes of activities-based science and an integrated curriculum are indeed valuable; and elementary teachers already possess many of the qualities of effective science teaching.

Convincing and persuasive argument is only the first step in establishing a program, however. Teachers want substantial, concrete, and activity-oriented inservice that gives them material they can take back to the classroom. Recently, curriculum developers have responded to the need for a science program that can be adapted to fit the specific teacher, learner, and community situation. While teacher acceptance and enthusiasm are important factors in innovation, teachers themselves need the continued support of the administration and community in their efforts.

Of all the factors involved in elementary science instruction, the teacher is the key. In a study of excellent science teaching,

Penick notes that the size of the budget, the school, or the community are not the limiting factors. He says, initially, the teachers are the most significant factor. Teachers in each of the exemplary programs want to teach science. They are dynamic, thoughtful, young-at-heart, eager to learn with their students, and they are professional educators. (Kyle, 1984, p. 17)

The science supervisor would do well to take advantage of and build upon the strengths and knowledge already at hand in his or her district.

References

Bethel, L. (1984). Science teacher preparation and professional development. In D. Holdzkom & P. Lutz (Eds.), *Research within reach: Science education* (pp. 143–157). Washington, DC: National Science Teachers Association.

Bethel, L., Ellis, J., & Barufaldi, J. (1982). The effects of a NSF institute on inservice teachers' views of science and attitudes toward environmental science education. *Science Education, 66*(4), 643–651.

Bredderman, T. (1982). Activity science—the evidence shows it matters. *Science and Children, 20*(1), 39–41.

Costenson, K., & Lawson, A. (1986). Why isn't inquiry used in more classrooms? *The American Biology Teacher, 48*(3), 150–158.

Crocker, R. (1984). Determinants of implementation of an elementary science program. *Journal of Research in Science Teaching, 21*(2), 211–219.

DeRose, J., Lockard, J., & Paldy, L. (1980). The teacher is the key: A report on three NSF studies. In *What are the needs in precollege science, mathematics and social science education? Views from the field* (pp. 43–52). Washington, DC: National Science Foundation.

Education USA report: Exemplary science (1983. May 30). *Education USA*, p. 316.

Helgeson, S., Blosser, P., & Howe, R. (1977). *The status of precollege science, mathematics, and social science education: 1955–1975. Vol. 1. Science education.* Columbus, OH: Center for Science and Mathematics Education, The Ohio State University.

Holdzkom, D., & Lutz, P. (Eds.) (1984). *Research within reach: Science education.* Washington, DC: National Science Teachers Association.

Koballa, T. (1984). Goals of science education. In D. Holdzkom & P. Lutz (Eds.), *Research within reach: Science education* (pp. 25–39). Washington, DC: National Science Teachers Association.

Koballa, T., & Bethel, L. (1984). Integration of science and schools subjects. In D. Holdzkom & P. Lutz (Eds.), *Research within reach: Science education* (pp. 79–107). Washington, DC: National Science Teachers Association.

Koballa, T., & Rice, D. (1985). Six strategies for improving attitudes toward science. *Science and Children, 22*(6), 32–34.

Kyle, W. (1984). Curriculum development projects of the 1960s. In Holdzkom, D. & Lutz, P. (Eds.), *Research within reach: Science education* (pp. 3–24). Washington, DC: National Science Teachers Association.

Mechling, K., & Oliver, D. (1982, November). The fourth R: Science: Stepchild of the elementary curriculum. *Principal*, 1–8.

Mechling, K., & Oliver, D. (1983a, March). Activities, not textbooks: What research says about science programs. *Principal*, 41–3.

Mechling, K., & Oliver, D. (1983b, October). Who is killing your science program? *Science and Children, 21*(2), 15–18.

Mechling, K., & Oliver, D. (1983c). *Promoting science among elementary school principals: Handbook IV. What research says about elementary school science.* Washington, DC: National Science Teachers Association.

National Science Foundation. (1980). *What are the needs in precollege science, mathematics and social science education? Views from the field.* Washington, DC: Author.

National Science Teachers Association. (1982). *Science-technology-society: Science education for the 1980s.* (NSTA position statement). (Available from the National Science Teachers Association, 1742 Connecticut Ave . NW, Washington, DC, 20009.)

Panel on School Science Commission on Human Resources of the National Academy of Sciences, National Research Council (1980). The state of school science: A review of the teaching of mathematics, science, and social studies in American schools, and recommendations for improvements. In *What are the needs in precollege science, mathematics and social studies education? Views from the field.* (pp. 79–120). Washington, DC: National Science Foundation.

Pratt, H. (1981). Science education in the elementary school. In N. Harms & R. Yager (Eds.), *What research says to the science teacher: Vol. 3* (pp. 73–93). Washington, DC: National Science Teachers Association.

ERIC. (1982). The S in "back to basics" stands for science. *Science education fact sheet, No. 2.* Columbus, OH: ERIC Clearinghouse for Science, Mathematics and Environmental Education.

Sigda, R. (1983). The crisis in science teaching and the realities of science teaching in the classroom. *Phi Delta Kappan, 64*(9), 624–627.

Smith, H. (1980). AAAS: A report on the implications for the science community of three NSF-supported studies of the state of precollege science education. In *What are the needs in precollege science, mathematics and social studies educa' ' Views from the field* (pp. 55–76). Washington, DC: ' al Science Foundation.

Shy. asky, J., Kyle W & Alport, J. (1983). The effects of new science curricula on student performance. *Journal of Research in Science Teaching, 20*(5), 387–404.

Stake, R., & Easley, J. (1978). *Case studies in science education.* Urbana, IL: Center for Instruction Research and Curriculum Evaluation, University of Illinois.

Voss, B. (1984). Student achievement in science: Curriculum and teaching strategies. *Metropolitan Detroit Science Review, 43*(4), pp. 28–32.

Weiss, I. (1978). *Report of the 1977 national survey of science, mathematics and social studies education.* Washington, DC: National Science Foundation.

Welch, W. (1981). Inquiry in school science. In N. Harms & R. Yager (Eds.), *What research says to the science teacher: Vol. 3* (pp. 53–72). Washington, DC: National Science Teachers Association.

Wellman, R. (1978). Science: A basic for language and reading development. In M. B. Rowe (Ed.), *What research says to the science teacher: Vol. 1* (pp. 1–12). Washington, DC: National Science Teachers Association.

White, R. & Tisher, R. (1986). Research on natural sciences. In M. Wittrock (Ed.) *Handbook of research on teaching.* (3rd ed.). (pp. 874–905). New York: Macmillan Publishing Co.

Yager, R. (1983a). Crisis on science education. *School Science and Mathematics, 84*(3), 189–197.

Yager, R. (1983b). In defense of societal issues as organizers for school studies. *School Science and Mathematics, 83*(8), 651–53.

Yager, R., & Bonnstetter, R. (1984). Student perceptions of science teachers, classes, and course content. *School Science and Mathematics, 84*(5), 406–14.

Ann Towsley in a graduate student in Elementary Education at the University of Michigan. She was a classroom teacher for 14 years, and specialized in elementary-level math and science for much of that time. Her major research interest is in the area of elementary science and math, and she has authored several articles on elementary math education.

Burton E. Voss has been a science educator at the University of Michigan since 1963. His major interests in research and development have focused on instruction interaction analysis, science attitudes, inservice teacher education, curriculum development, science program evaluation, and most recently, on the use of microcomputer simulators for analyzing teaching strategies. He has been involved in NSF programs, Chautauqua science updates, and the development of new field biology laboratories. The self-assessment project has been one of his major activities for NSTA.

Disseminating Research About Science Education

22

PATRICIA E. BLOSSER
THE OHIO STATE UNIVERSITY

The science supervisor has many responsibilities: among them is assisting teachers in translating research findings into classroom practice. This activity is a never-ending one and has long been a concern of the science education community (Helgeson, Blosser, and Howe, 1977; Yager, 1978; Butts et al., 1978).

This chapter presents an overview of some of the research recently published in science education journals, explores possible reasons why teachers do not use research, and concludes with some dissemination models that supervisors and other science educators might consider.

Research on Learning

Cognitive Development

Science education researchers appear to have accepted Piaget's ideas of the developmental stages through which children pass. Concrete operational students, no matter what their chronological age, appear to benefit from the physical manipulation of objects, which implies the need for laboratory or other hands-on activities. The age at which manipulation ceases to be important is likely to depend on the kind of learning activity involved. If the activity is dull but instructive, a student will need to manipulate the materials. If the activity is interesting, the student can benefit from a demonstration while the teacher emphasizes the important features (Herron et al., 1975).

Concept Formation, Conceptual Understanding

There is a large body of research on science concept formation, much of it being carried out at the University of Wisconsin. These studies have shown that students appear to need exposure to instances when a science concept both does and does not fit a circumstance. Also, research has revealed that students' understanding is based on their interpretation of past experiences rather than on scientific knowledge. Many researchers are currently working on the problem of students' misconceptions. (Champagne and Klopfer, 1983; Gilbert, 1983). In 1983 the first international seminar on misconceptions in science and mathematics was held at Cornell University (Helms and Novak, 1983).

Although instruction can correct some gross misconceptions, they generally remain unaltered and impede learning if not directly confronted and addressed. Misconceptions may be widespread and appear to be unrelated to aptitude or level of cognitive development. Children may hold views of the world that differ from those commonly accepted in science. Their teachers need to be aware of this fact and need to learn to use strategies that help their pupils resolve the cognitive conflict between their views and those of scientists. Teachers need to have a better understanding of the interaction of cognitive development, notions regarding causality, and conceptual understanding so they are better able to choose instructional strategies for science (Olstad and Haury, 1984). The judicious choice of science textbooks alone will not resolve the problem of misconceptions. This problem is compounded by the fact that teachers themselves may hold misconceptions similar to those of their students (Gilbert, 1983).

A number of science education researchers have advocated the use of the learning cycle in science teaching to promote concept formation (Ward and Herron, 1980; Renner et al., 1984, 1985, 1986; Saunders and Shepardson, 1984; and Smith and Lott, 1984), although the results of their studies vary. Smith and Lott (1984) state that four conditions must exist if students are to reevaluate their misconceptions: (1) students must be dissatisfied with existing conceptions, (2) the new conceptions must be intelligible, (3) the new conceptions must be initially plausible to students, and (4) the new conceptions should appear fruitful, leading to new insights and discoveries.

Problem Solving

Problem solving is another area of research that has appeared in the annual reviews of the National Association for Research in Science Teaching–Educational Resources Information Center (NARST–ERIC) and is currently receiving emphasis in other content areas under the heading of thinking skills. Problem-solving and process skills in science are clearly related, so making sure students use science process skills as they learn science concepts will contribute to the development of problem-solving skills. Multiple approaches to instruction should be used to accommodate differences in cognitive development among pupils. Problem-solving activities should include concrete representation and hands-on experiences. Also, if students are given familiar variables to work with, they will be able to concentrate on acquiring new skills in controlling variables (Helgeson, in press).

Relevance to Teachers and Supervisors

Teachers need to use these research findings as they teach. They need to be able to analyze the learning patterns of their students and to respond with appropriate teaching strategies.

Research on Teaching

A current theme of the research on teaching is the interaction within classrooms. Researchers have quantified and analyzed classroom verbal and/or nonverbal behavior (Balzer, Evans, and Blosser, 1973). The research continues (Anderson, 1984). Numerous studies on teachers' questioning behaviors and use of wait time have been published. Researchers have concluded that the types of questions teachers ask do influence student achievement; that teachers need to ask more questions that promote higher-level thinking; that teachers who can learn to wait longer for students to think before providing a response, or wait longer before taking over the discussion following a response will have more students involved in discussion, receive more thoughtful answers, and encourage more student-student (as opposed to teacher-student) interaction (Rowe, 1974: McGlathery, 1978; Blosser, 1979; Tobin and Capie, 1981).

Research on teaching from other fields has relevance for science educators. This research has been summarized by Berliner (1984) as relating to

- preinstructional factors: decisions about content, time allocation, pacing, and grouping
- during-instruction factors: engaged time, time on-task, time management, monitoring success rate, academic learning time, monitoring during seat work or activities, structuring, and questioning
- climate factors: communicating academic expectations for achievement; development of safe, orderly, and academically focused work environments; sensible management of deviant behavior, and developing cooperative learning environments
- post-instructional factors: testing, grading, and providing feedback to students

Some science education research studies have been conducted on the factors identified by Berliner. Fraser and Fisher (1983) have created instruments to assess the science classroom's psychosocial environment. Sanford (1984) and others have studied the management of science classrooms. Methods for gathering quantitative data on teaching behaviors and procedures for conducting qualitative studies in science classrooms exist and are available for teachers to use on their own.

Research shows that teachers dominate classroom talk and ask most of the questions, many of which stimulate only low-level thinking; that the use of hands-on activities in science classes has declined (Stake and Easley, 1978) and is continuing to decline (Weiss, 1986); and that low-achieving students have less engaged student time in science than do high achievers (Stallings, 1982) as well as less variation in the activities they undertake. Apparently, findings from research studies have not yet been translated into classroom practice.

Why Don't Teachers Use Research?

Why have research findings had so little impact on classroom practices? Reasons probably vary with the individual teacher, but some generalizations can be made. First, teachers have to know the research. For this to occur, teachers must either read journals in which the research is reported or attend meetings of professional associations where papers based on research studies are presented. Both of these activities involve time and money. Teachers are busy with daily routines that must be followed if they are to survive in their classrooms. Their days often end before the daily chores are completed. When teachers can find time to read beyond the sources they need for planning and teaching, they probably do not read the science education journals in which research data are reported.

Even if teachers look at the research journals, they might doubt if wading through all the jargon and statistics is worth getting to the small section on implications for classroom practice, if indeed such a section can be found in the research article. Journals have space limitations, and authors are faced with decisions about what to report and what to omit. They are, for the most part, writing for other researchers; thus, sections which translate research findings into classroom practice are brief, if included at all.

Teachers attend meetings of professional associations to acquire ideas and teaching techniques they can use with their pupils. They attend workshops and sessions in which other teachers report; they are not likely, however, to choose a research-focused session unless these sessions are clearly identified as having implications for classroom practice. This is the practical approach to take when time is limited or new ideas are needed: go to the practitioner who functions daily in the same situation as other teachers, rather than to the researcher, whose time is spent in another environment.

Also, it is possible, as Berliner (1984) has written, that teachers do not use research because it has been oversold: they have a pervasive mistrust of research, and much research on teaching is of recent development. Rogers has asserted that practitioners tend to ignore research studies and reports because many of these reports are "...jargon-laden, pretentious, and unclear" (1984).

Third, most conventional educational researchers do not involve their subjects—the teachers—in the research itself. The teacher-subjects have little to say about the purposes, timing, methods, and tests involved. Rogers characterized teachers as perceiving research as a "hit-and-run" activity. Roney (1984) cites research's lack of attention to context and overemphasis on means instead of ends as sources of discouragement to teachers.

Information from science education research must be in a form that enables teachers to consider alternatives, to make more informed professional judgments, and to refine the commonsense knowledge and theories which guide their actions (Power, 1984).

The Dissemination of Research

Before research findings can be implemented in the classroom, they have to be written in a form that teachers find useful and have to be disseminated by some means to their intended audience. This dissemination can take place in several ways.

Publications

In 1978 the National Science Teachers Association began publishing a series of books on *What Research Says to the Science Teacher.* Research articles also appear under the same title in the four NSTA journals. These articles translate research findings about a specific topic to implications for classroom practice. They do not stress research methods or statistical techniques but provide information on findings of changes in classroom techniques.

The Appalachia Educational Laboratory, Inc., in Charleston, West Virginia, has produced several publications entitled *Research Within Reach...* in which authors identify and briefly discuss research findings that can be used by teachers. *Research Within Reach: Science Education* (1984) focuses on science education and is available from the National Science Teachers Association.

The National Diffusion Network (NDN) produces a publication entitled "Educational Programs That Work." This publication contains descriptions of programs judged as "exemplary" by the Department of Education's Joint Dissemination Review Panel. The panel looks for cognitive and affective gains presented by each project. Information provided for each exemplary program includes the target audience, description of the program, evidence of effectiveness, implementation requirements, financial requirements, services available, and the individual(s) to contact for further information.

A variety of publications can be found through ERIC. ERIC is a network of clearinghouses on different subjects located across the country. Sponsored by the U.S. Department of Education, these clearinghouses produce digests and information bulletins targeted to readers within a specific clearinghouse's scope area. In addition, they also produce Information Analysis Products (IAPs) intended for teachers of different grade levels. For example, the ERIC Clearinghouse for Science, Mathematics, and Environmental Education (ERIC/SMEAC) has produced *Especially for Teachers–Science, 1966–1981*, a collection of over 900 citations on the teaching of science. This document focuses on teaching activities and curriculum materials rather than on research. The digests and information bulletins provide teachers with a current awareness of research-based information related to science, mathematics, and environmental education.

In addition, all ERIC clearinghouses contribute materials to two monthly publications, Resources in Education (RIE) and Current Index to Journals in Education (CIJE). These monthly publications are found in 771 different locations in the continental United States, as well as in additional locations in U.S. territories and foreign countries (Brandhorst and Eustace, 1986). The ERIC database contains research reports, curriculum materials, speeches, papers presented at professional society meetings, and so on, and is the fourth most-used database in the United States (Brandhorst and Eustace, 1986).

From time to time the National Assessment of Educational Progress (NAEP) issues reports based on research in science education. Surveys are conducted involving 9-year-olds, 13-year-olds, 17-year-olds, and young adults (ages 26 to 35) to assess their knowledge and attitudes. Science assessments have been conducted in 1969–70, 1972–73, and 1976–77 by NAEP, and in 1981–82 by researchers at the University of Minnesota (Rakow, Welch, and Hueftle, 1984). These surveys are reported in both technical reports and in journal articles.

In 1984 NARST began the publication of *Research Matters...To the Science Teacher.* These short publications highlight research findings relevant to teachers. While they provide an overview of research findings, they do not contain citations of relevant literature for those who wish to read more on the topic. Instead, the reader is urged to contact the author of *Research Matters* for further information.

Reports of science education research are also issued by state departments of education and by the Department of Education's regional labs and centers.

In fact, so much research-based information is available that has relevance for classroom practice that a science supervisor could spend all of his or her time identifying and disseminating such information.

Networks

John Goodlad, in his report of a large-scale study of American education entitled A *Place Called School* (1984), suggested that schools should join with other schools that are endeavoring to improve education. According to Goodlad, "...schools that set out to be self-renewing by themselves will probably not get as far as schools that set out to be renewing within a context of support" (Quinby, 1985). NDN uses an information dissemination model with two types of change facilitators: program developers and regionally based facilitators. Program developers are technical experts on specific programs or innovations. Facilitators link the program developer, the local educational agency, and the local schools interested in using the innovation. Facilitators provide assistance, coordinate activities of potential and current users, and maintain contact with school systems as the change process takes place.

The NDN model presents supporting research evidence and actively promotes effective science education innovations, rather than indiscriminately disseminating information about research findings.

Sometimes informal networks exist among school administrators and other leaders in neighboring school systems. Strong instructional leadership has been cited as a key element in the effective schools literature (Purkey and Smith, 1982); administrators or supervisors alone, however, cannot bring about the cooperation of teachers.

Responding to Teachers' Concerns

Supervisors not only want to tell teachers about research on teaching, learning, and implementation, they want teachers to apply relevant findings. Supervisors can provide teachers with copies of articles, summaries of research, and results of database searches: they can facilitate the granting of release time and travel monies to attend professional meetings, and so on. While these activities help teachers become aware of information they might use, they do not necessarily result in the next step—the use of this information by teachers in their planning and teaching.

If teachers are to use the available information, they must see a need for its use and feel secure enough to attempt to introduce the innovation into their daily routine. It is at this point in the change process that information about the Concerns /Based Adoption Model (CBAM) described by Hall, Wallace, and Dosett (1973) becomes important for supervisors to know about and act upon. (For a detailed discussion of the CBAM Model, see "Managing Change in the Science Program" in this volume.)

Supervisors need to help teachers become aware of and use research about teaching, learning, and implementation. This task, like so many others in education, is more complex upon examination than it may appear at first glance. Supervisors must be aware of information sources in which research data have been communicated in a form useful to teachers. Supervisors also need to look particularly for the sections of research reports in which conclusions and implications are discussed. Journals such as those published by the National Science Teachers Association and the School Science and Mathematics Association regularly include articles emphasizing what research says to the teacher. The members of the National Science Supervisors Association (NSSA), either as individuals or as an organization, may want to encourage the staff of other journals to include this feature in their publications.

The most effective mechanism for communicating relevant research to teachers will vary with the supervisors and the teachers on their staff. Some supervisors may send out a quarterly newsletter identifying research related to one of more of the instructional factors; other supervisors may want to circulate copies of articles covering specific topics to interested teachers. Supervisors may also hold periodic update sessions on classroom research as part of inservice or staff development activities.

References

Anderson, Charles W. (Ed.) .(1984, December). *Observing science classrooms: Observing science perspectives from research and practice.* Columbus, OH: Association for the Education of Teachers in Science in Cooperation with the ERIC Clearinghouse for Science, Mathematics, and Environmental Education

Balzer, A. LeVon, Evans, Thomas P., & Blosser, Patricia E. (1973, December). *A review of research on teacher behavior relating to science education.* Columbus, OH: Association for the Education of Teachers in Science and the ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Berliner, David. (1984). The half-full glass: A review of research on teaching. In P. L. Hosford (Ed.), *Using what we know about teaching.* (pp. 51–77). Alexandria, VA: Association for Supervision and Curriculum Development.

Blosser, Patricia E. (1979). *Review of research: Teacher questioning behavior in science classrooms.* Columbus, OH: ERIC Clearinghouse for Science, Mathematics and Environmental Education.

Brandhorst, Ted, & Eustace, Joanna. (Eds.). (1986, May). *Directory of ERIC information service providers.* Washington, DC: ERIC Processing and Reference Facility.

Butts, David P., et al. (1978, March). Priorities for research in science education: A Delphi study. *Journal of Research in Science Teaching, 15*(2), 109–114.

Champagne, Audrey, & Klopfer, Leo. (1983, January). *Naive knowledge and science learning.* Paper presented at the annual meeting of the American Association of Physics Teachers, New York, NY. (ERIC Document Reproduction Service No. ED 225 852)

Especially for teachers: ERIC selected documents on the teaching of science 1966 to 1981. (1982, December). Columbus, OH: ERIC Clearinghouse for Science, Mathematics and Environmental Education.

Fraser, Barry J., & Fisher, Darrell. (1983). *Assessment of classroom psychosocial environment.* Workshop manual. Bentley, Australia: Western Australia Institute of Technology.

Fuller, Frances F. (1969). Concerns of teachers: A developmental conceptualization. *American Educational Research Journal, 6*(2), 207–226.

Gilbert, John K. (1983, January). *Alternative conceptions: Which way now?* Paper presented at the annual meeting of the American Association of Physics Teachers, New York, NY. (ERIC Document ED 225 851)

Goodlad, John I. (1984). *A place called school.* New York: McGraw-Hill Book Company.

Hall, Gene E. (1986, March). General Session Speech presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco, CA.

Hall, Gene E., Wallace, Richard C., Jr., & Dosett, William F. (1973). *A developmental conceptualization of the adoption process within educational institutions.* Austin, TX: Research and Development Center for Teacher Education, The University of Texas.

Helgeson, Stanley L. (in press). *Problem solving in middle/junior high school science education.*

Helgeson, Stanley L., Blosser, Patricia E., & Howe, Robert W. (1977). *The status of pre-college science, mathematics, and social studies education: 1955–1975. Vol. 1. Science education.* Columbus, OH: Center for Science and Mathematics Education, The Ohio State University.

Helms, Hugh, & Novak, J.D. (1983, July). *Proceedings of the international seminar in science and mathematics.* Ithaca, NY: Cornell University.

Herron, J. Dudley, et al. (1975). A summary of research in science education: 1974. In Leo Klopfer (Ed.), *Science Education.* New York: John Wiley and Sons. (ERIC Document ED 116 965)

Holdzkom, D., & Lutz, P. (1984). *Research within reach: Science education.* Washington, DC: National Science Teachers Association.

Loucks, Susan F., Newlove, B.W., & Hall, Gene. (1975).

Measuring levels of use of the innovation: A manual for trainers, interviewers, and raters. Austin: Research and Development Center for Teacher Education, The University of Texas.

McGlathery, Glenn. (1978). Analyzing the questioning behaviors of science teachers. in M. B. Rowe (Ed.), *What research says to the science teacher: Vol. 1.* (pp.13-30). Washington, DC: National Science Teachers Association.

Olstad, Roger G., & Haury, David. (1984). A summary of research in science education: 1982. *Science Education, 63*(3). (ERIC Document ED 241 350)

Power, Colin. (1984). Tinker, tailor, soldier, spy: Implications of science education research for teachers. *Science Education, 68*(2), 179–193.

Purkey, Stewart C., & Smith, Marshall S. (1982, December). Synthesis of research on effective schools. *Educational Leadership, 40*(3), 64–69.

Quinby, Nelson. (1985, March). Improving the place called school: A conversation with John Goodlad. *Educational Leadership, 42*(6), 16–19.

Rakow, Steven J., I. Welch, Wayne W., & Hueftle, Stacey J. (1984). Student achievement in science: A comparison of national assessment results. *Science Education, 68*(5), 571–578.

Renner, J.W., et al. (1984). *Sequencing language and activities in teaching high school physics.* (A report to the National Science Foundation.) (ERIC Document ED 238 732)

Renner, J.W., et al. (1985, April). The importance of the form of student acquisition of data in physics learning cycles. *Journal of Research in Science Teaching, 22*(4), 303–325.

Renner, J.W., et al. (1986). *Biology Teacher's Guide. Investigations in Natural Science.* Norman, OK: Science Education Center, University of Oklahoma. (ERIC Document ED 260 928)

Rogers, Vincent R. (1984). Qualitative research: Another way of knowing. In P. L. Hosford, (Ed.), *Using what we know about teaching* (pp. 85–106). Alexandria, VA: Association for Supervision and Curriculum Development.

Roney, Anne. (1984). The price of everything, the value of nothing. In P. L. Hosford, (Ed.), *Using what we know about teaching* (pp. 109–111). Alexandria, VA: Association for Supervision and Curriculum Development.

Rowe, Mary Budd. (1974). Wait time and reward as instructional variables, their influence of language, logic and fate control. Part one: Wait time. *Journal of Research in Science Teaching, 11*, 81–94.

Rowe, Mary Budd. (1978). *What research says to the science teacher: Vol. 1.* Washington, DC: National Science Teachers Association.

Sanford, Julie P. (1984, September). Management and organization in science classrooms. *Journal of Research in Science Teaching, 21*(6), 575–587.

Saunders, W.L., & Shepardson, D. (1984, April). *A comparison of concrete and formal science instruction upon science achievement and reasoning ability of sixth grade students.* Paper presented at the 57th annual meeting of NARST, New Orleans, LA. (ERIC Document ED 244 797)

Smith, E. L., & Lott, G.W (1984). *Ways of going wrong in teaching for conceptual change: Report on the conceptual change project.* East Lansing, MI: Institute for Research in Teaching, Michigan State University. (ERIC Document ED 242 769)

Stake, Robert E., Easley J., et al. (1978). *Case studies in science education. (Vol. I). The case reports.* Washington, DC: U.S. Government Printing Office. (ERIC Document ED 166 058)

Stallings, J. (1982). Applications of classroom research of the 1970s to mathematics and science instruction. In R. E. Yager, (Ed.), *What research says to the science teacher: Vol. 4.* (pp. 7-21). Washington, DC: National Science Teachers Association.

Tobin, Kenneth G., & Capie, W. (1981). *Wait time and learning in science.* AETS Outstanding Paper for 1981. Burlington, NC: Carolina Biological Supply Company.

Ward, C.R., & Herron, J.D. (1980, September). Helping students understand formal chemical concepts. *Journal of Research in Science Teaching, 17*(5), 387–400.

Weiss, Iris J. (1986). The 1985 national survey of science and mathematics education. In A. Champagne & L. Hornig (Eds.), *Forum '86: The School Curriculum.* Washington, DC: American Association for the Advancement of Science.

Wise, Kevin, & Okey, James. (1983). A meta-analysis of the effects of various science teaching strategies on achievement. *Journal of Research in Science Teaching, 20*(5), 419–435.

Yager, Robert E. (1978, March). Priorities for research in science education: A study committee report. *Journal of Research in Science Teaching, 15*(2), 99–107.

Yeany, Russell H., & Miller, Ann P. (1983). Effects of diagnostic/remedial instruction on science learning: A meta-analysis. *Journal of Research in Science Teaching, 20*,(1), 16–19.

Patricia E. Blosser is Professor of Science Education, the Ohio State University, and the Associate Director of User Services, ERIC Clearinghouse for Science, Mathematics, and Environmental Education in Columbus, OH. She is the author of numerous articles relating to science education research. Her major research interest is in teacher behavior, especially questioning skills.

Classroom Environment and Teaching Science

23

DAVID P. BUTTS
RONALD D. SIMPSON
THE UNIVERSITY OF GEORGIA

Much in the same way the cell is the basic unit of life, the classroom is the basic unit of schooling. The similarity is striking in that, while a cell must have genetic instructions, a source of energy, and synthetic capabilities to fully function, a classroom works best when a curriculum, students, and teachers become integrated into a system. This interaction between curriculum, teachers, and students will be the focus of this chapter. A classroom must also have a supporting environment provided by school administrators and parents. While these will not be discussed directly, their indirect influences are components of schooling.

We have constructed a model of the components and dynamics of the classroom in Figure 1. We shall discuss here the internal elements depicted in the model: teacher, student, peers, and science. The interactions between these factors create the three climates of the classroom: social, instructional, and learning. The external factors of schooling—administrators, parents, and community—are present and exert continual influence. Our discussion here will be limited to the internal factors associated with classroom climates.

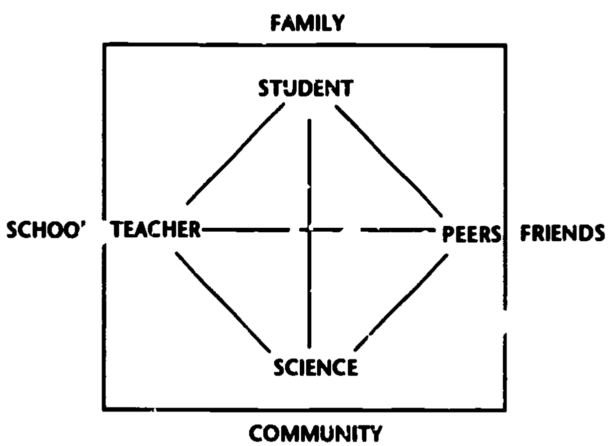


Figure 1. Model depicting the principal components and interactions of the classroom.

Final performance and attitudes toward learning are influenced by the student's initial performance and attitudes, as well as by his or her classroom, peer group, and home environment.

Getzels and Thelen (1960) developed a model in which the classroom was viewed as a social system encompassing the interactions between the personalities, needs, role expectations, and classroom climate that influence behavior. Walberg (1968) and several of his associates used this model to examine the internal environments of Harvard Project Physics classes. They demonstrated that the classroom environment predicts both cognitive and affective learning outcomes; cognitive aspects of the classroom are better predictors of cognitive outcomes, and affective aspects of the classroom are better predictors of affective outcomes.

Simpson and Troost (1982) examined relationships between the variables of self, home, and school, and attitudes toward science and science achievement in grades 6 through 10. They hypothesized that each variable had a moderate to strong relationship with students' attitude toward science and achievement in science. Recent reports by Talton and Simpson (1985) have confirmed these relationships.

Haladyna and his co-workers developed a model that examines the relationships between students, teachers, the learning environment, and attitudes toward science (Haladyna, Olsen, and Shaughnessy, 1982, 1983). The model divided the variables into two categories: those that are directly influenced by the school environment (endogenous) and those that are not (exogenous). Findings from these studies indicated that the learning environment is strongly related to attitudes toward science, and the science teacher can mediate the effects of the learning environment on student attitudes toward science.

Studies on what creates an effective school consistently found that schools with clear academic goals, a supportive learning climate, on-task instruction, and frequent monitoring and feedback give students a good probability of success (Butts, Dennison, and Simpson, 1987). Schools lacking these four characteristics have students with less probability of success, even though they may have resources available to them that are usually expected to support success.

According to the research on effective schooling, four groups of people are essential to the development of these characteristics—students, teachers, administrators, and parents or community. As noted by West (1986), successful schools are those where the most

> *...compelling determinant in the long process was not only adherence to high standards for students, but also equal attention to making sure that everyone who influences individual children does everything possible to help them learn. As one teacher told a site visitor, 'we gang up on kids so they can't fail.' (p. 187)*

In these schools, the entire community is committed to providing students with maximum opportunity. In this open environment, students and teachers work hard to achieve common goals.

Social Climate

Figure 2 depicts the basic components of a classroom's social climate. The teacher's interaction with each learner and the multidimensional interactions among students themselves constitute the science classroom's complex social system. Since young people are by nature social beings, this aspect of classroom climate needs to be understood by science teachers.

Talton and Simpson (1985) found that the attitudes of individuals toward science correlated strongly with their perception of peer attitudes. This correlation rose from sixth to ninth grade and then leveled off. Talton and

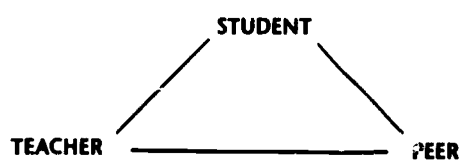


Figure 2. Model depicting social climate in the classroom.

Simpson concluded that adolescent students seek to share the attitudes of their peers, and that this relationship was strongest in the ninth grade, a time when most young people approach physical maturity.

The nature of group dynamics and the way in which students interact with each other and with their teachers holds profound implications for teaching and learning. In the past, many teaching strategies and curricula viewed the student as an autonomous, independent learner. In fact, today's students are sophisticated social beings who are greatly stimulated and influenced by those significant others around them. Hence, both science curriculum and instruction should take into account the social climate of the classroom. When this climate is positive, when there is mutual trust and respect, and when members of the group can take risks, a new potential for effective science teaching and learning comes into being.

A key role for science teachers is to generate, nurture, and maintain a social climate that supports academic learning. Teachers, students, administrators, and parents must understand and accept academic learning as the primary purpose for schooling. They must set consistently high expectations for schooling routines and enforce them fairly. Specifically, four elements must be developed to create a supporting social climate:

- Students need access to a reasonable set of classroom and school rules that are enforceable (Kounin, 1977; Brophy 1979; Squires, 1980; Sanford and Evertson, 1981; D'Amico. 1981: Evertson, 1982; Emmer, 1981; Anderson, 1982; Bickel, 1983; Eubanks and Levine, 1983; Howe, 1984; Blum, 1984).
- Students clearly know the rules for appropriate and acceptable behavior in the classroom and school (Ruff, 1978; Squires, 1980; D'Amico, 1981; Anderson, 1982; Blum, 1984).
- Students avoid disrupting the class and expect to experience the consequences if they do (Squires, 1980; D'Amico, 1981; Anderson, 1982; Blum, 1984).
- When correction is needed, it is clearly delineated and handled in a timely fashion (Squires, 1980; D'Amico, 1981; Anderson, 1982).

Thus, a supporting social climate incorporates all the players—students, teacher, administrator, and parents—in an orderly environment that clearly defines expected behaviors. The consequences for departure from these boundaries are administered in a timely way to support rather than discourage the learner.

Instructional Climate

The teacher, student, and science curriculum constitute the instructional climate of the classroom. In Figure 3, one can see that the ways in which the teacher interacts with each student, the ways in which each student interacts with science, and the ways in which the teacher relates to science together set the instructional tone in each classroom.

A paramount aspect of instructional climate is the way students and teachers feel toward each other. For example, if teachers show respect for students, and thus establish high expectations for learning, higher levels of learning will indeed follow. The development of such positive attitudes facilitates a more intense relationship with science. If students have strong positive feelings toward their teacher, and their

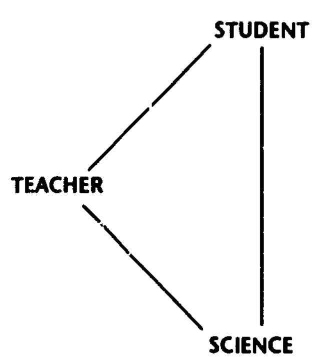


Figure 3. Model depicting instructional climate in classroom

teacher presents science in a manner consistent with the nature of science, then students will experience science in ways otherwise not possible.

The most effective learning results from classroom experiences planned in advance and articulated with a clear congruence between goals, activities, and tests. Such instruction is the product of teachers who teach toward clearly defined student goals, and who are skillful in maintaining extensive contact with their students both in and out of the classroom through relevant and monitored homework. Four elements indicate an effective instructional climate:

- The instruction is designed to fit the individual needs of students and takes into account their prior learning, their naive conceptual frames of reference, and their learning styles (Anderson 1982; Bickel, 1983; Blosser, 1988a; Blum, 1984; Brinckerhoff and Yager, 1985).
- Instruction is based on a mastery learning strategy recognizing that all must achieve, but that some may need more time or alternative pathways (Squires, 1980; D'Amico, 1981; Blosser, 1984b).
- The on-task instruction gives the learner the time and resources he or she needs for learning (Ruff, 1978; Brookover, 1981; Anderson, 1982; Eubanks and Levine, 1983; Bickel, 1983; Mitman and Osaki, 1984; Blum, 1984; Howe, 1984; Blosser, 1984b).
- Instruction is based on the assumption that students are indeed individually responsible for their learning, and that this responsibility is recognized and accepted by all players (Squire, 1980; Evertson, 1981; Brown, 1983; Blum, 1984; Brinckerhoff and Yager, 1985).

Learning Climate

This part of the classroom climate embraces important educational outcomes in our society (see Figure 4). The achievement in and commitment to science that our young people experience while in our schools establish a base

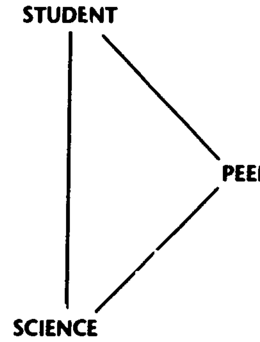


Figure 4. Model depicting learning climate in the classroom.

from which successive interactions with science emanate. Oliver and Simpson (1986) found that achievement in and attitudes toward science in the tenth grade are excellent predictors of how much exposure to science students will seek in the future. For example, those students who are successful in tenth grade biology are much more likely to enroll in eleventh grade chemistry; those that do are much more likely to take additional science courses beyond high school.

A positive learning climate results from clear academic goals, operationally defined as the basic knowledges and skills derived from personal construction by students who know what is expected of them, who expect to do well, and who have access to frequent assessment and feedback.

To monitor their own progress, students need clear goals and a means to demonstrate achievement. Effective schooling studies show the learning climate can be enhanced through the following elements:

- Students gain the knowledge and skills for the tasks that will be used to assess their progress (Squires, 1980; Brown, 1983; Anderson and Smith, 1985).
- Students are helped to construct this knowledge, not merely exposed to it (Squires, 1980; Blosser, 1983; Brinckerhoff and Yager, 1985).
- Students know what is expected of them (Brookover 1981).

• There is a continuous diagnosis of student progress, with teachers monitoring homework, class work, and tests (D'Amico, 1981; Anderson, 1982; Eubanks and Levine, 1983; Bickel, 1983; Howe, 1984; Blum, 1984)

• Feedback on student performance is reasonably prompt (Bickel, 1983; Purkey, 1983; Blum, 1984).

This chapter began with an analogy. We likened the science classroom to a cell. As with any system, there are components, a source of energy, and interactions. In the classroom, the components are the teacher, the students, and the curriculum. Goals and expectations serve as sources of energy, and learning becomes the end result of all the interactions.

If we believe that the classroom is the basic unit supporting our educational system, that the nature of the components comprising a science classroom make a difference, and that these interactions can lead to powerful learning outcomes, then we have a foundation on which to build for the future. Healthy organisms are a result of strong cells and a positive supporting environment. An effective educational system is the result of positive classroom environments surrounded by sound administrative, family, and community support systems. Research results now support what many of us had already suspected: positive social, instructional, and learning climates lead to positive cognitive and affective learning. If we believe that this model accurately predicts educational outcomes, then we have a key that can be used to improve science instruction in our schools.

References

Anderson, L. W. (1982). *Teachers, teaching, and educational effectiveness.* Columbia, SC: College of Education, University of South Carolina.

Anderson, C .W., & Smith, E. L. Teaching science. In V. Keohler (Ed.), *The educators handbook: A research prospectus* (114–143). New York: Longman, Inc. (in press).

Berliner, D. C. (1979). Tempus educare. In P. Peterson & H. Walberg (Eds.), *Research in Teaching* (120–135). Berkeley: McCutchan.

Bickel, W. E. (1984, April). Effective schools: Knowledge, dissemination, inquiry. *Educational Researcher*, pp. 3–4.

Block, J. H., & Burns, R. B. (1976). Mastery learning. In L. S. Schulman (Ed.), *Review of research in education* (Vol. 4). Itasca, IL: F. E. Peacock.

Blosser, P. E. (1984a). A review of research within reach: science education. *ERIC/SMEAC Science Education Digest Number 2.* Columbus, Ohio: ERIC Clearinghouse for Science, Mathematics and Environmental Education.

Blosser, P. E. (1984b). Some implications for science education from national reports. *ERIC/SMEAC Science Education Digest Number 1.* Columbus, Ohio: ERIC Clearinghouse for Science, Mathematics and Environmental Education.

Blum, R. E. (1984). *Effective schooling practices: A research synthesis.* Portland, OR: Northwest Regional Educational Laboratory.

Brinckerhoff, R. F., & Yager, R. E. (1985). *Science and technology education for tomorrow's world: A report of the Exeter II conference on secondary science education.* Washington, DC: National Science Teachers Association.

Brookover, W. B. (1981). *Effective secondary schools.* Philadelphia, PA: Research for Better Schools, Inc.

Brophy, J. (1979, December). Teacher behavior and its effects. *Journal of Educational Psychology, 71,* 733–750.

Brown, J. L. (1983). On teaching thinking skills in the elementary and middle school. *Phi Delta Kappan, 65,* 709–714.

Butts, D., Dennison, J., & Simpson, R (1987). Making science user-friendly for teachers and their students. *Education, 108*(2), 193-203.

Cohen, M.(1981, April-May). Effective schools: What the research says. *Today's Education,* pp. 46–48.

D'Amico J. L. (1981). *The effective schools movement: Studies, issues, and approaches.* Philadelphia, PA: Research for Better Schools, Inc.

Emmer, E. T., Evertson, C. M., & Anderson, L. (1982). *Improving classroom management: an experimental study in junior high classrooms.* Austin, Texas: R & D Center for Teacher Education, The University of Texas at Austin.

Eubanks, E. E., & Levine, D. U. (1983). A first look at effective schools projects in New York City and Milwaukee. *Phi Delta Kappan, 65,* 697–702.

Evertson,C.M., Emmer,E.T., & Brophy, J.F (1982). *Improving classroom management: An experimental study in elementary classrooms.* Austin, Texas: R & D Center for Teacher Education, The University of Texas at Austin.

Fisher, C., Marliave, R., & Filby, N. (1979). Improving teaching by increasing academic learning time. *Educational Leadership, 37,* 52–54.

Getzels, J.W., & Thelen, H. A. (1960). The classroom as a unique social system. In Nelson B. Henry (Ed.), *National Society for the Study of Education Yearbook* (pp. 53-81). Chicago, IL: University of Chicago Press.

Haladyna, T., Olsen, R., & Shaughnessy, J.(1982). Relationships of student, teacher, and learning environment variables to attitudes toward science. *Science Education, 66*(5), 671–687.

Haladyna, T., Olsen, R., & Shaughnessy, J. (1983). Correlates of class attitude toward science. *Journal of Research in Science Teaching, 20*(4), 311–324.

Howe, R. (1984). *School improvement program: Columbus public schools, 1984–1985.* Columbus, Ohio: Columbus Schools Report.

Keeves, J.P. (1975). The home, the school, and achievement in math and science. *Science Education, 59*(4), 439–460.

Kounin, J.S. (1977). *Discipline and troop management in classrooms.* Huntington, NY: Robert E. Krieger Publishing Company.

Mitman, A.L., & Osaki, S.Y. (1984, April). *Life science instruction and its relationship to scientific literacy at the intermediate level.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, LA.

Oliver J.S., & Simpson. R.D. (in press). Influences of attitude toward science, achievement motivation, and self concept on commitment to science: A longitudinal study. *Science Education*

Purkey, S.C., & Smith, M. S. (1983, March). Effective schools—A review. *Elementary School Journal, 83,* 422–452.

Ruff, F.K. (1978). *Instructional variables and student achievement in reading and mathematics: A synthesis of recent process-product research.* Philadelphia, PA: Research for Better Schools Inc.

Sanford, J., & Evertson, C. (1981). Classroom management in a low SES junior high: Three case studies. *Journal of Teacher Education, 32,* 34–38.

Simpson, R. D., & Oliver, J. S. (1985). Attitude toward science and achievement motivation profiles of male and female science students in grades six through twelve. *Science Education, 69*(4), 511–526.

Simpson, R. D., & Troost, K.M. (1982). Influences on commitment to and learning of science among adolescent students. *Science Education, 66*(5), 763–781.

Squires, D. A. (1980). *Characteristics of effective schools: The importance of school processes.* Philadelphia: Research for Better Schools Inc.

Talton, E. L., & Simpson, R. D. (1985). Relationships between peer and individual attitudes toward science among adolescent students. *Science Education, 69*(1), 19–24.

Walberg, H. J. (1968). Structural and affective aspects of classroom climate. *Psychology in the Schools, 5,* 247–253.

West, A. C. (1986, November). The search continues for effective schools. *Phi Delta Kappan, 68,* 187–188.

Wynne, E.A. (1980). *Looking at schools: Good, bad, and indifferent.* Lexington, MA: D.C.Heath & Company.

David P. Butts is an Aderhold Distinguished Professor of Science Education at the University of Georgia, where he has taught for the past 15 years. Prior to that, he was part of the Science Education Center at The University of Texas. He is the author of more than 350 books, chapters, articles, and other publications on the teaching of science. His major research interest has been in the design and implementation of improved teaching practices in the elementary and secondary science classroom.

Ronald D. Simpson is currently the director of the Office of Instructional Development at the University of Georgia. He has taught at both the University of Georgia and North Carolina State University. Based on his wide experience in the teaching of secondary biology, he has numerous publications related to science teaching and influencing the affective development of students. His major research interests continue to be in the relationships of the affective domain and student learning in science.

The Effectiveness of Science Supervisors

24

WILLIAM C. RITZ
CALIFORNIA STATE UNIVERSITY

Supervision: the action, process, or occupation of supervising; esp.: a critical watching and directing (as of activities or a course of action).

WEBSTER'S 9TH NEW COLLEGIATE DICTIONARY, 1983

There are many ways of supervising science; not all of these are ways of helping people teach science better.

PARAPHRASED FROM A STATEMENT WHICH ORIGINALLY APPEARED IN *ENVIRONMENTAL STUDIES.*

It was 3:00 on a rainy Friday afternoon late in spring when Chris's boss, the assistant superintendent for curriculum and instruction for the Hepplewhite Schools said in passing, "By the way, Chris, we'll be getting your evaluation started pretty soon. Let's get together next week some time to talk more about it."

Since Chris was just nearing the end of a year of service as Hepplewhite's K–12 science coordinator, the evaluation would be a first, both for Chris and for the district. Frequently during that weekend, Chris' thoughts returned to the evaluation. What form will the evaluation take? Who will be doing it? What will they be looking at? What if George Grinch, the chemistry teacher at Glenoaks High, tells them about the scrap we got into about the new computer software? How will they really know how good a job I've been doing?

While every science supervisor wants to do a good job, most of us really don't give much day-to-day thought to "supervisor effectiveness," except perhaps at evaluation time. At that point, we realize just how hard it is to define "effective." Defining effective science supervision is as challenging as trying to define good teaching. We can perhaps best approach the question through a series of approximations. As each facet is revealed, we can begin to better understand what the phrase "effective science supervision" does in fact mean.

TABLE 1
Overall Rank-Order of Supervisor Activities (n = 265)

Rank Order	Activity	Corresponding Mean Value
1	Consulting with Teachers	3.669
2	Teaching of Pupils	3.574
3	Curriculum Activities	3.511
4	Activities re Supplies/Equipment	3.376
5	Evaluation of Teaching	3.093
6	Consulting with Administrators	3.046
7	Observations of Classroom Teaching	2.889
8	Reports/Research	2.828
9	Formal Meetings	2.812
10	Consulting with Pupils	2.763
11	Preparation Time	2.582
12	Social Interaction	2.492
13	Classroom Demonstration Teaching	1.773
14	Conducting In-Service Workshops	1.533
15	Co-Teaching a Classroom Lesson	1.438
16	Inter-School Transportation	1.245
17	Observation of another Supr/Admin.	1.135

From "A Profile of Science Supervision in New York State" by W. Ritz and M. Felsen, 1976, *Science Education, 60*(3), p. 343. Reprinted by permission.

Who Are We Talking About?

When Chris and the boss met the following week, Dr. Oobleck suggested that they look at a supervisor checklist used by an administrator from the nearby Chippendale district last year. As they looked at it, however, it became apparent that, while the checklist was intended for evaluating science supervision, many of its criteria were based on activities in which Chris had not been involved. They wondered about this until Chris remembered that B. J., the science supervisor at Chippendale, worked exclusively with teachers in grades 7–12.

Our problems begin with the title "science supervisor." We use that title as though it were just one type of position, but this is not the case. Instead, one finds people assigned to a wide variety of responsibilities. Regardless of their specific job title, they think of themselves as science supervisors, and so do their employing school districts. Our first challenge, then, is to consider the many permutations found under the generic title "science supervisor."

The most common position titles appear to be those of "science supervisor," "science consultant," and "science department chairperson." In our study of science supervision in New York state (Ritz and Felsen, 1976), we found the latter position to predominate (82.1 percent) among those persons identified on the State Department of Education roster of science supervisory personnel. Only about 12 percent of those responding actually used the specific title "science supervisor," and less than one-half of a percent called themselves "science consultants." In addition, another 5 percent identified themselves with titles different again from these three. In attempting to deal with science supervision, then, it seems important to first ascertain what position is under consideration. In some of the research, all titles are lumped together under a generic "science supervisor" category (for example, Ritz, Cashell, and Felsen, 1981), but others such as Perrine (1984) have focused exclusively on just one of several subclasses. Nothing is inherently wrong with either approach, but it's helpful to know what position is the focus of any given study.

What Is the Science Supervisor's Role?

A few days later, someone gave Chris a copy of an evaluation questionnaire which came from State University. The good news was that this instrument was designed for supervisors working K–12, just like Chris. Furthermore, this questionnaire had been used in several research studies across the country and its content validity had been checked by a panel of experts. Chris anticipated that they had at long last found an appropriate vehicle for use back at Hepplewhite. The bad news, though, was that the activities

still didn't match the things Chris had worked so hard to accomplish this past year.

Any discussion of effectiveness must assess and consider the specific tasks the science supervisor undertakes. Several studies have addressed this question. In our 1976 study (Ritz and Felsen), 265 "science supervisors" (note the generic title) described their work week by rating 18 supervisory activities on a 5-point scale. The activities on the questionnaire were identified by a group of science supervision interns who worked from their own ...s to summarize their many activities into the 18 categories. Table 1 displays the overall activity rank-ordering that emerged from this study. Note that the activity ranked second (teaching of pupils) probably reflects this study's preponderance of science department chairpersons, most of whom teach at least half-time. Table 2, on the other hand, compares the ranking of these activities by "chairpersons of science departments" with those calling themselves "science supervisors." It is important to note that respondents were instructed to answer in terms of what they typically do; because of this, a particular response did not necessarily reflect how that person might have rated the importance of that activity.

In 1981, the National Science Teachers Association (NSTA) published results of a survey on the perceived role of the K–12 science supervisor (note their specification of the position title) based on data gathered at three 1978 NSTA area conventions. This report (Beck et al., 1981) was based on 210 surveys received from 162 teachers, 24 administrators, and 30 "others." At the top of the list (most beneficial as science supervisory roles) were activities related to instruction, followed by curriculum, staff development, implementation, management, assessment, and, lastly, "assignment, transfer, load" (staffing). Interestingly, there does not seem to be much difference in perceptions at the three different grade-level categories reported (K–6, 7–9, 10–12). Where differences did exist, the teachers of grades 10–12 were the ones who viewed the supervisory role differently from the other two groups.

TABLE 2
Rank-Ordered Supervisor Activities: Comparison of Science Supervisors with Department Chairpersons

Science Supervisor (n = 32)	Chairperson of Science Dept. (n = 218)
1.,2. Consulting with Teachers and Curriculum Activities	1. Teaching of Pupils
	2. Consulting with Teachers
3. Consulting with Administrators	3. Curriculum Activities
4. Supplies/Equipmen	4. Supplies/Equipment
5. Evaluation of Teaching	5. Evaluation of Teaching
(Items 6 through 12 not applicable)	
13. Inservice Workshops	13. Classroom Demonstration Teaching
14. Classroom Demonstration	14. Inservice Workshop Teaching
15. Co-Teaching	15. Co-Teaching
16. Inter-School Transportation	16. Inter-School Transportation
17. Observation of Another Supervisor/Administrator	17. Observation of Another Supervisor/Administrator

From "A Profile of Science Supervision in New York State" by W. Ritz and M. Felsen, 1976, *Science Education, 60*(3), p. 346. Reprinted by permission.

In contrast, Perrine (1984) focused his attention on elementary science supervisors, examining and contrasting the views of elementary teachers and their science supervisors. He also examined the influence of a wide variety of demographic variables on elementary teachers' perceptions of their science supervisors. Twenty-nine elementary science supervisors and 470 randomly-selected K–8 teachers from New Jersey were asked to respond to 32 questions from two standpoints: the supervisor's actual and ideal performance. Perrine's instrument included the following components of supervision: communication, working relationship, leadership style, creativity/confidence, personnel position, initiating structure, consideration, and decision making. However, analysis of the teacher perceptions yielded just two factors which accounted for 74 percent of the variance for the "actual" and 80 percent of the "ideal." Perrine identified these as (1) provision of technical expertise and/or assistance and (2) humanistic interaction with teachers.

Madrazo and Hounshell (1987) examined the role expectancy of the science supervisor by administering the "Science Coordinators Role Expectations Questionnaire" (Ortiz Plata, 1977) to over 500 North Carolina superintendents, supervisors, principals, elementary and secondary teachers, and college professors. (Note the instrument's use of the "coordinator" position title.) The questionnaire's 48 items fall into 5 subscales—the coordinator as: (1) a resource in science teaching, (2) a resource for implementing the science program, (3) a resource for inservice programs, (4) a leader in science teaching, and (5) a supervisor of science. Their research findings supported the view of Anderson (1972) that a supervisor's role is perceived differently by different people. The greatest difference appears to exist with respect to Subscale 5, the coordinator as a supervisor of science. Role expectations which suggest "evaluation" functions seem to produce the greatest divergence of attitude. We shall return to this point later.

Our 1981 study (Ritz, Cashell, and Felsen) yielded results similar to those of Perrine in terms of the science supervisor's role. With 143 supervisors and 258 of their teachers responding to a science supervision rating scale (SSRS), four factors, which we labeled "instructional intervening," "interpersonal/supporting," "management/planning," and "socializing," emerged from the combined group analysis, and these bear a strong likeness to the two factors identified by Perrine. It seems safe to say that the science supervisor's role can be perceived as having at least two major components which we referred to as the "formal" and "nonformal" components of science supervision.

Job descriptions typically focus on the "formal" component, which Perrine refers to as "technical expertise and/or assistance," and with which the NSTA survey seems primarily to have been concerned. Our research, in some ways corroborated by Perrine, seems to be telling us that the "nonformal" component, Perrine's "humanistic interaction," is as important. The nonformal, humanistic component may even serve as a kind of catalyst which enables the formal aspects of supervision to succeed. However, before we examine that notion, it would be helpful to more fully consider the formal and nonformal dimensions of supervision.

The Formal and Nonformal Dimensions of Supervision

Very frustrated in not finding an appropriate evaluation instrument, Dr. Oobleck and Chris finally decided to simply convert Chris' job description into an evaluation checklist. That seemed like a good idea to Chris, until a careful reading of the checklist they drafted made clear that many activities that had taken much effort were still not represented. Chris pointed out for example, how much effort had gone into convincing teachers that their new science supervisor was going to be working with them as a colleague. Where would participating in potluck suppers and faculty Christmas parties fit into the job description? And what about substitute teaching for Sally Van Wolverton one afternoon last winter, so she could get to her son's tuba recital over in River City? As a result of that simple gesture of friendly collegiality, Sally became one of Chris' most outspoken advocates in one of the District's most difficult schools.

The "formal" relationship that exists between teachers and their supervisors is generally established through a job description set forth in the school district policy handbook. The rationale is rather straightforward: carefully spell out the position responsibilities so that productive supervisor-teacher relationships and effectiveness can be more readily achieved and assessed. A clearly delineated statement of expectations can also be comfortable to the supervisor, who now feels that he or she knc what performance is expected.

In reality, things do not work quite this way. Experienced supervisors know that their "real" job description extends far beyond the written one. In addition to fulfilling a set of formal organizational tasks, supervisors also need to attend to the "informal" dimensions of the supervisor-teacher relationship. Job descriptions typically sound as though one could carry out each task in a vacuum. However, the settings in which science supervision are carried out are social systems, and the tasks of the science supervisor inevitably involve interacting with teachers and others. The quality of the supervisor's informal relationship with teachers plays a major and perhaps catalytic role in determining what can be accomplished.

This view receives strong substantiation from our research (Ritz, Cashell, and Felsen, 1981), as well as from Perrine's study (1984). Using instruments based on our earlier research, we asked science supervisors and a sampling of their teachers to express their views on supervisory effectiveness by rating 26 formal and nonformal supervisory activities. Examples of formal activities included curriculum work, inservice workshops, and observation of classroom teaching. Nonformal activities included helping a teacher with a personal problem, facilitating interpersonal relationships among staff, and protecting staff from undeserved criticism.

We also wanted to compare science supervisor and science teacher views on the quality of the supervisor's relationships with teachers, what might be called the supervisor's "group membership." In order to assess this, we used a modification of the "Person-Group Relationship Scale" (Felsen and Blumberg, 1973, a, b, c). We were especially interested in exploring the relationship that might exist between group membership status and the supervisor's perceived effectiveness. To what extent are teachers' ratings of the effectiveness of science supervisors influenced by the supervisor's interpersonal skills?

We hypothesized that science supervisors who develop a relationship with a high degree of attraction (how much the supervisor is attracted to membership with the faculty) and acceptance (how much the faculty accepts the supervisor as a member) will be seen by those teachers to be more effective than those whose relationships are less positive. To examine that relationship, we used a statistical procedure that attempts to explain the relationship between two variables, which in this case were psychological group membership and supervisory effectiveness.

Two statistically significant correlations emerged from that analysis. The first relationship showed group membership to account for about 39 percent of the variance in supervision effectiveness. The items from our instruments which best explain this relationship suggest that general interpersonal/communication behaviors are the source of this correlation. The second relationship, accounting for about 3 percent of the variance shared by the two instruments, is personal liking for the supervisor. It appears that the supervisor's group membership status strongly influences his or her perceived job effectiveness. Furthermore, our analysis seemed to show that the supervisor's interpersonal/communication behavior could be changed to obtain more positive perceptions of his or her job effectiveness.

When Perrine (1984) analyzed teachers' perceptions of both the ideal and the actual supervisory behavior, he identified only two main factors pertinent to supervisory effectiveness: (1) provision of technical expertise and/or assistance, and (2) humanistic interaction with teachers. He described the first factor as being "instruction-oriented," whereas the second was said to be related to what he termed "professional skills."

The message emerging from these studies seems clear: science supervisors who are perceived as being effective do more than meet the "formal" expectations of their job descriptions. They also carry out nonformal, people-oriented activities that help them to become better integrated into their faculty groups. When they do so, teacher perceptions of their effectiveness become more positive.

The Different Perspectives of Teachers and Supervisors

Ultimately, Chris and Dr. Oobleck decided to ask a random sample of teachers to help evaluate the science supervision at Hepplewhite. Rather than focus exclusively on Chris's performance, they decided to ask teachers and the other subject matter supervisors to rate the science supervision in terms of both the "ideal" and the "actual." From this, they hoped to get some good ideas about services that teachers desired, as well as an assessment of the services already being provided.

Characterizing it as a kind of "cold war," Blumberg (1974) described the relationship between supervisors and teachers in these words:

> *Teachers tend to say that they find their supervision of little value. Supervisors say their work has a lot of value. Supervisors seem to be saying that they want to spend more time doing what their clients (the teachers) consider to be relatively useless. (p. 13)*

Most research examining teacher and supervisor views on the supervisor's role or effectiveness finds that teacher and supervisor perceptions tend to be contradictory. But, while our findings (Ritz et al., 1981) proved to be no exception, we also identified a number of important areas of agreement. More about these later on. Recall that our study identified four factors which tend to influence supervisor effectiveness: (1) instructional/intervening; (2) interpersonal/supporting; (3) management/planning; and (4) socializing. Two additional factors we examined, attraction and acceptance, relate to group membership status. Teacher and supervisor views differed significantly on four of these six factors. In the following three cases, supervisors rated themselves as being more successful than did their teachers:

- instructional/intervening activities (such as inservice workshops and co-teaching)
- interpersonal/supporting activities (such as helping teachers with personal problems, informal communications, and mediating conflict)
- acceptance in the faculty group (in terms of how truthful, argumentative, or friendly supervisors can be)

Only with respect to one factor, "socializing activities" (involving teachers in social events or supporting faculty social events), did the teachers rate the supervisors as being more effective than they rated themselves. In Perrine's research (1984), disagreement between the perceptions of teachers and those of science supervisors was greater in terms of the ideal role expectation of supervision than for actual supervisory practice. Teachers also expressed higher expectations of science supervision than the supervisors themselves. Furthermore, both groups considered the current leadership behavior of the science supervisor to fall far short of the ideal.

Madrazo and Hounshell (1987) also identified differences in science supervisor role expectations. Administrators and teachers (both elementary and secondary) differed with respect to "the coordinator as a resource for implementing the science program" (orienting teachers in the preparation of daily lesson plans, help in preparing demonstration lessons, and discussing science lessons and course plans with teachers). In general, administrators also saw the science supervisor's role differently with respect to the coordinator as a supervisor of science. Administrators favored having the supervisor make regular visits to schools, and following up those visits with meetings or conferences and written reports. The greatest divergence of opinion is seen with regard to what can be termed "evaluation" functions of supervision, a point to which we will examine shortly.

It would be unfair to focus exclusively on supervisor-teacher differences of opinion, for our research also uncovered a fair number of points of agreement. Figure 1 displays the ten activities that our samples of supervisors and science teachers said supervisors do most effectively. Note that while the rankings differ,

Figure 1. Contrasting Top Ten Supervisory Activities Handled Most Effectively as Ranked by Science Supervisors and by Science Teachers

Rank	Science Supervisors	Science Teachers
1.	Actvities relating to supplies/equipment	Activities relating to supplies/equipment
2.	Supporting creative ideas originated by teachers	Consulting with administrators
3.	Consulting with administrators	Informal communication and dialogue with staff
4.	Curriculum activities	Supporting creative ideas originated by teachers
5.	Informal communication and dialogue with staff	Protecting staff from undeserved criticism
6.	Getting to know staff as individuals	Getting to know staff as individuals
7.	Observation of classroom teaching	Curriculum activities
8.	Mediating conflict between teachers and others	Helping a teacher with a personal problem relating to school
9.	Protecting staff from undeserved criticism	Mediating conflict between teachers and others
10.	Evaluation of teaching	Giving personal feedback relative to teaching performance

From "'Cold war' between supervisors and teachers?" by W. Ritz and J. Cashell, 1976, *Educational Leadership, 38*(1), pp. 77–78.
Reprinted by permission of the Association for Supervision and Curriculum Development and the authors.

eight of the ten activities appear on both lists. Both groups felt the supervisors were most effective in dealing with supplies and equipment, activities of special significance in science teaching. It was nice, too, to find that both teachers and supervisors saw their supervisors as supportive of the creative ideas originated by teachers.

Attaining More Positive Teacher Perceptions of Science Supervision

During their evaluation discussions, Chris and Dr. Oobleck were delighted to notice that teacher evaluations of Hepplewhite's science supervision were generally on a par with the evaluations provided by Chris' administrators. By contrast, most of the published studies showed teacher perceptions to be less positive. That in turn prompted them to wonder how Chris managed to attain these results. What, they wondered, set Chris' performance apart from what is more often seen?

In discussing perceptions of supervisor behavior and relationships, Blumberg (1980) stressed the need for supervisors to strike a balance between "the energy devoted to the task itself and that devoted to the development of healthy relationships among the people working on the task." While the results of our 1981 study of New York state science supervisors indicated a fairly good balance in terms of activities accomplished, some key aspects of disagreement did exist that should not be ignored. A key area of concern appears to be the realm we labeled "interpersonal/communication" activities. In view of the strong statistical relationship observed between these activities and teacher ratings of supervisory effectiveness, science supervisors should make a concerted effort to develop healthy relationships with and among their teacher clients. This is certainly not to say that nothing else counts, for teachers certainly do expect high-quality services from their supervisors. But too many supervisors may focus their efforts too narrowly on "job description" tasks, when in fact, teachers clearly expect more.

Striving for Excellence in Science Supervision

As Chris and Dr. Oobleck worked their way through Chris' evaluation (which was, incidentally, very positive), they talked at some length about goals for the coming year, deciding on a few things for special emphasis. As their discussion continued, it became clear that certain kinds of administrative commitment would be required for these to become attainable goals. Because Dr. Oobleck and the other administrators could not pledge all that would have been required, they negotiated a reduced and more feasible set of goals for the coming year. During their talks, the conversations inevitably turned to the evaluation of teachers. Dr. Oobleck proposed that Chris begin to actively participate in these evaluations because, "As science supervisor, you are the expert on what good science teaching should look like. None of the administrators in the Hepplewhite District understand science and science teaching the way you do." Not having been involved in teacher evaluation before this, Chris wondered how it might affect the collaborative relationship that was currently being established. "Up to this point, I've been a helping colleague to the science teachers of this district. What will this do to the trust I've worked so hard to establish?"

It is important for administrators and science supervisors to realize that excellence in science supervision requires more than assigning a person to develop a better science program, even if that person is a knowledgeable, hardworking individual. Excellence in science supervision requires a concerted effort toward which a wide variety of human and fiscal resources must be committed. The "Criteria for Excellence in Science Supervision" of NSTA's Search for Excellence in Science Education (SESE) remind us of several necessary types of institutional commitment. In addition to the more obvious commitments called for (such as an adequate budget for supplies, equipment, and staff development), the criteria also specify administrative support to provide a science center, to facilitate communication linkages, to foster ongoing staff planning, and to support planning and curriculum development. Clearly, those who specified these criteria understood that a science supervisor cannot attain excellence without strong administrative support and commitment.

Criteria for Excellence in Science Supervision

Excellence in science supervision is evidenced by a science supervisor who

- has the necessary scientific knowledge to communicate successfully with science teachers
- is professionally active in and out of his/her district
- works with teachers in planning and implementing after-school and summer enrichment opportunities for students
- provides leadership and assistance in identifying creative and talented science students

Excellent science supervision is evidenced by planning and curriculum development which

- takes the long-range view
- has the support of teachers and the administration
- bases curriculum revision on current research, and on an assessment of goals and objectives that meets the needs of the local community and of society at large
- includes all dimensions of science education—content, process, attitudes, science and society, science and technology
- uses a grading/reporting system that is consistent with the nature of science

Excellent science supervision is evidenced by a program of inservice opportunities which

- provides experiences which are tied to the curriculum and to long-range plans, goals, and objectives

- includes a science center to which teachers can come to share, solve, and create
- enables teachers to study, evaluate, and recommend solutions to local problems of concern to them
- addresses the professional development of individual teachers

Excellent science supervision is evidenced by an administration which supports science education by

- providing an adequate budget for supplies, equipment, and staff development
- cooperating with teachers to identify strengths and remedy weaknesses
- facilitating communication linkages between classroom teachers, administration, and the local governing board
- fostering ongoing staff planning (*Criteria for Excellence*, 1987)

Administrative support for the science supervisor can and should also take other forms. There is, for example, the matter of determining what the supervisor is expected to do. The concern here is not with most of the activities typically found on a science supervisor's job description. The decision about what tasks to include or exclude is mostly a matter of deciding what needs to be done and how much time and energy the supervisor should devote to it. Quite different, however, is the decision as to whether the supervisor should have to evaluate teachers (or science teaching, if you prefer). This decision should be most carefully considered. Several studies have suggested that it might be better to separate "consultative" functions (most of what most science supervisors do) from "evaluative" functions. When Schrigley (1980) examined science supervisor characteristics that influence their credibility with teachers, he concluded that

> *The data imply that the office of the credible supervisor is a service, rather then a rating, agency. The supervisor who rates teacher performance may not find it easy to establish the credibility desired to influence teachers' attitude positively toward science. (p. 165)*

Madrazo and Hounshell (1987) similarly raise concerns about the evaluation function, indicating that "...[evaluation] is probably where the divergent attitudes among the various groups of educators showed most." Based on our several studies of supervisor activities and supervisor effectiveness, we speculated that the most important factor hampering effective interpersonal/communication activities, which we found to be critical in determining teacher ratings of supervisor effectiveness, may be the evaluation function. If this is true, the suggestion of a recent working group of the Association for Supervision and Curriculum Development (ASCD) (Sturges, 1979) to separate administrative and consultative supervisory roles is worth heeding.

Regardless of whether or not such a separation of functions exists, school districts should exert great care in selecting persons to serve as supervisors. Most supervisors seem to move into their new positions as a result of demonstrated success in the classroom, which does not assure success as a supervisor. Perhaps a more important criterion would be the candidate's high level of skill in working with a broad variety of people.

One has also to consider to what extent science supervisors have been trained to work with adult clients within the school organization. Blumberg (1980) found that some 20 percent of the supervisors he studied "located the source of their problems in themselves, most typically in their feelings that their communications skills were inadequate." Should school districts require or at least provide such training to their supervisors?

There is also the matter of rewards. To what extent do school districts provide incentives for supervisors to devote attention to the interpersonal aspects of their work? Far too often, success in the institutional sense is linked almost completely to the formal job description. If the school fails to view what the supervisor does to develop close working relationships with teachers as important, it runs the risk of encouraging supervisors to neglect these aspects of the position.

By whatever means, it is essential that science supervisors work diligently to improve the interpersonal/communication aspects of their supervision. It is certainly doubtful that teachers would rate as successful a supervisor who failed to meet their minimum expectations with respect to the "formal" activities of the position, no matter how great their interpersonal skills. However, no matter how well those formal functions may be met, still greater success can be attained by the supervisor who does so while also developing a strong, trusting relationship with teachers who are, after all, the supervisor's clients.

References

Beck, Essie et al. (1981, April). *Perceived roles of the science supervisor by K–12 teachers and administrators.* Paper presented to the National Science Teachers Association Board of Directors, New York, NY. (ERIC Document Reproduction Service No. ED 253 296).

Blumberg, Arthur. (1980). *Supervisors and teachers: A private cold war.* (2nd ed.) Berkeley, CA: McCutchan Publishing Co.

Criteria for excellence. (1987). Washington, DC: National Science Teachers Association.

Felsen, M., & Blumberg, A. (1973a, March). *Student membership relations in the classroom group.* Paper presented before the American Educational Research Association, New Orleans, LA.

Felsen, M., & Blumberg, A. (1973b). *Teacher membership relations in the faculty group.* Study, Syracuse University, NY.

Felsen, M., & Blumberg, A. (1973c). Classroom group membership: An unexplored dimension of school life. *Journal Supplement Abstract Service, Vol. 3* (MS No. 495). Washington, DC: American Psychological Association.

Felsen, M., & Ritz, W. (1979, October). Science supervision in New York state: An examination of supervisor-faculty relationships. *School Science and Mathematics 89*(6), 465–472.

Madrazo, G. Jr., & Hounshell, P. (1987). The role expectancy of the science supervisor: Results of research in science supervision. *Journal of Research in Science Teaching 71*(1), 9–14.

Perrine, Walter G. (1984). Teacher and supervisory perceptions of elementary school personnel. *Journal of Research in Science Teaching,68*(1), 3–9.

Ortiz Plata, G. (1977). Expectations for the role of the science coordinators in Puerto Rico as perceived by themselves and their immediate role associates at the school district level. (Doctoral dissertation, New York University). *Dissertation Abstracts International, 38,* 1797A–1798A.

Ritz, W., & Cashell, J. (1980, October). 'Cold war' between supervisors and teachers? *Educational Leadership, 38*(1), 77–78.

Ritz, W., & Felsen, M. (1976). A profile of science supervision in New York state. *Science Education,60,* 339–351.

Ritz, W., Cashell, J., & Felsen, M. (1981). The effectiveness of science supervisors and their membership status within a faculty. *Journal of Research in Science Teaching, 18*(3), 229–240.

Schrigley, Robert L. (1980). Science supervisor characteristics that influence their credibility with elementary school teachers. *Journal of Research in Science Teaching, 17*(2), 161–166.

Sturges,A.W.(1979).Instructional supervisors: A dichotomy. *Educational Leadership, 36,* 586–589.

William C. Ritz, Director of the Science and Math Education Institute of California State University, Long Beach, has taught science at a variety of levels and has also helped to train science supervisors. His publications include research studies that explore various aspects of science supervision. His efforts at present focus on science teacher education at both the elementary and secondary school levels.