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ABSTRACT

This report describes the kinds of preparation and continual staff development elementary school teachers need to help them acquire the knowledge, skills, and attitudes to foster science learning. In addition, the conditions and support needed to create an environment where good science teaching can flourish are discussed. Chapters included are: (1) "Introduction" (discussing the settings for science teaching and teacher knowledge and skills); (2) "Teacher Development" (discussing early, middle, and later phases); (3) "Organizational Structures and Support" (describing clear purposes and outcomes, resources and allocation, conception of staff development, organizational norms, involvement in decision making, and leadership and support); and (4) "Recommendations" (containing 11 suggestions for the local, state, or national level). (YP)

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The National Center for Improving Science Education

Developing and Supporting Teachers for Elementary School Science Education

SE 050 679

A PARTNERSHIP OF THE NETWORK, INC AND THE BIOLOGICAL SCIENCES CURRICULUM STUDY (BSCS)

The NETWORK, Inc.

BSCS
The Natural Selection

Developing and Supporting Teachers for Elementary School Science Education

by

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1989

The National Center For Improving Science Education

A Partnership Of

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FOREWORD

This report is one of a series produced by the National Center for Improving Science Education. The Center's mission is to promote changes in state and local policies and practices in the science curriculum, science teaching, and the assessment of student learning in science. To do so, the Center synthesizes and translates the findings, recommendations, and perspectives embodied in recent and forthcoming studies and reports in order to develop practical resources for policymakers and practitioners. Bridging the gap between research, practice, and policy, the Center's work is intended to promote cooperation and collaboration among organizations, institutions, and individuals committed to the improvement of science education.

The synthesis and recommendations in this report were conducted with the help of the study panel whose members are listed in the front of this report. We gratefully acknowledge the help given to us by many individuals who have supplied materials, and made recommendations and suggestions for the text of the report. We wish to thank Milbrey McLaughlin of Stanford University, who acted as an outside reviewer of the report, for her critical comments. Thanks are also due to the support of the Center's monitors at the U.S. Department of Education, John Taylor and Wanda Chambers.

Two other panels have produced companion reports on assessment and on curriculum and instruction. A summary report integrating all three of these documents will be prepared and will be available from the Center. This integrative report will be supplemented by implementation guides for state and district policymakers and practitioners, and by guidelines especially tailored for additional audiences including teachers, principals, school boards, parents, and teacher educators.

The Center, a partnership between The NETWORK, Inc., of Andover, Massachusetts and the Biological Sciences Curriculum Study (BSCS) of Colorado Springs, is funded by the U.S. Department of Education's Office of Educational Research and Improvement. Members of its Advisory Board are listed in the front of this report. For further information on the Center's products and work, please contact Senta Raizen, Director, National Center for Improving Science Education, 1920 L Street, Suite 202, Washington,

DC 20036, or Susan Loucks-Horsley, Associate Director, National Center for Improving Science Education, The NETWORK, Inc., 290 South Main Street, Andover, MA 01810.

CHAPTER I. INTRODUCTION

A Science Classroom

"How do seeds live? Can seeds grow way, way deep in the ocean and make seaweed?" "How do seeds get inside of watermelons?" "Hey! How do they make watermelons without seeds in them?" "How do seeds grow plants?" These were some of the many questions asked by Ms. Lopez's second graders. Today, they are thinking about seeds, the topic they are about to study, and Ms. Lopez is keeping track of these questions on a chart titled: "Questions We Have about Seeds." Another chart titled: "What We Know About Seeds" is filled with such statements as: "Seeds grow in gardens," "You can eat sunflower seeds," and "Carrots don't have seeds." These charts are referred to time and again as the teacher encourages questions to develop concepts and change opinions. Ms. Lopez uses the children's questions and comments to decide that the children are ready for a "seed walk."

The next morning, the students go to a nearby field to collect seeds. Each child, besides carrying a collection bag, wears an adult sock over one shoe and pulled up to the knee, providing a fuzzy surface to which seeds can cling. When the children return from the walk, they each select one seed to study carefully with a hand lens. After each child makes observations about what the seed looks, feels, and smells like, and guesses how it might have traveled, the child makes a presentation to the group in the meeting circle. The teacher keeps track of the kinds of seeds discussed by taping the specimens onto a chart. After the children tally the number of the different kinds of seeds the group has collected, they develop picture graphs of the results.

That evening, after the "seed walk," Ms. Lopez reflects on the differences in the children's understandings of the structure and function of seeds. She notes which children easily made observations and which ones had more difficulty, which children made more obvious or more unexpected responses, and which children seemed comfortable using the lens for examining their seeds and which ones seemed more awkward. As she thinks of the multiple activities for the next day, Ms. Lopez uses her notes to place children in groups so that their discussions will prompt and challenge one another's inquiry.

The next day, some groups count the seeds on their socks and then plant them in large plastic baggies, watering and setting them in the window area. In the days that follow, they will be encouraged to observe the germination process carefully and compare the total number of seeds with the number that sprouted by making "ratio" sentences. Ms. Lopez invites other children to compare sizes of seeds by outlining the seeds on graph paper and then counting the number of graph squares each seed covers. The students discover there is a great diversity of sizes and *shapes in different kinds of seeds, and that the same kind of seed has variations in size and shape.*

Still other groups choose to continue working in the "seed journals" that she requires all to keep. They are either to paste in or draw the specimen and then "write" about three seeds of their choice, including the same sorts of observations they shared earlier in meeting circles. Since students of this age have a range of "sentence" writing capabilities, the teacher meets with each child to discuss that individual's observations and writing. She uses the journals and evidence from the meetings to monitor the level of understanding the children have of such concepts as diversity and cycles.

Ms. Lopez's class spends most of the week working on this science topic, incorporating writing and math, as well as inquiry-based science activities. Other activities she will do with the children include: a fiction story about how a native American girl uses seeds and plants, a garden song, and drawing the seedlings as they sprout. Her thematic active learning approach is similar to that she observed and practiced during a year of induction, when she was coached by a mentor as she tried her first interdisciplinary unit.

In successive lessons, Ms. Lopez will call groups together and, based on their explorations, ask several questions. As she records the responses, Ms. Lopez will ask the children to clarify their answers. Eventually, she will introduce some new vocabulary information that helps the students to reflect on their developing concepts. Some of the children may not be sure about the new information; they will need more time to talk about it and do some additional testing of their ideas to help make the new information part of their personal understanding of seeds. Last year when she did this unit, for example, several youngsters insisted that the lima bean embryos they discovered earlier would grow into lima bean plants even without the "seed halves" attached. They were convinced that the embryos could "eat" the soil and water and grow into an "adult" lima bean plant. Through careful questioning, Ms. Lopez was able to guide these children to design a test of their beliefs. She found that these children changed their point of view after they conducted the investigation, and that they now had some additional questions to pursue.

After several weeks of studying seeds, Ms. Lopez recognizes that the children have learned a great deal about such science concepts as diversity, life cycles, and structure and function. They have become adept "observers" and ask questions of each other and of Ms. Lopez concerning these developing concepts. Ms. Lopez knows they will soon be ready to apply these new levels of knowledge and skills to other science areas. The children will, as a group, construct a booklet on how to plant seeds and care for the seedlings. Ms. Lopez will keep notes on the progress of individual children and the class as a whole. This will then help her plan and design more effective science instruction to use in future classes. It will also provide the source material that will enable her to make more formal assessments in report cards, in conferences with parents, and -- for the class as a whole -- to Mr. Sandowski, the 3rd grade teacher.

Science is a way of knowing about, understanding, interacting with, and appreciating the natural world, and Ms. Lopez's second graders are being given ample opportunities to do so. Yet such scenes are not characteristic of elementary school science lessons. Where Ms. Lopez begins by probing, questioning, and in other ways assessing the understandings her children bring to school, other teachers assume children come to school with few understandings that will help them learn science. Where Ms. Lopez uses children's questions, experiences and initial understandings to adapt and carefully structure hands-on inquiry activities, other teachers move lock-step through a series of curriculum activities. Where Ms. Lopez encourages a variety of ways for children to talk and write about their inquiries, guiding them towards the development of important concepts, other teachers, even if they use hands-on activities, allow insufficient time either before or afterwards for children to make meaning of their experiences. Where Ms. Lopez sees science as a coherent set of concepts and processes for children to know, that use language and mathematics skills as tools for exploring and communicating, other teachers relegate science lessons to a specific time segment in the day, rarely integrating it with other teaching content. And finally, where Ms Lopez monitors each child's progress for continual regrouping, differentiated assignments, and a record upon which to base more formal assessments, other teachers lead all children through the same experiences and rely heavily on written tests and the demonstration of effort for their formal assessments.

In fact, there is clear evidence that such science teaching does not occur in elementary classrooms, with significant consequences for both students and our country as a whole. Science teaching consists largely of lecture, with some discussion (Goodlad, 1984). Factual information, disconnected from experience and concept development, is stressed in teaching, in testing, and in the most commonly used curriculum materials -- textbooks (Bybee et al., 1989). As a consequence, science learning in our country is far below that in other countries (Lapointe, Mead & Phillips, 1989), students do not choose to take science courses when they have the option (Mullis & Jenkins, 1988), and the level of scientific literacy is far less than needed to make informed decisions about such issues as personal health, the environment, and energy use.

But there is reason to be optimistic. While some say that good teachers are born, not made, we believe that the understandings and abilities that teachers such as Ms. Lopez have about science and about science teaching are ones that all elementary school teachers can develop.

Since teachers play a primary role in creating opportunities and possibilities for learning it is critically important for a report on science education to consider how to maximize the capabilities of teachers to create learning experiences for their children. What do teachers need to know and be able to do to teach science well? How can they be assisted to learn and continuously renew their learning? What organizational policies and structures can support their teaching?

Overview of This Report

In this report we address each of these questions. We continue in this introduction to set the stage for our discussions of science teachers and teaching. We examine what is known -- and thus what science teachers need to know -- about children's learning, and about the science content and instructional strategies that best promote that learning. We ask, "Do elementary school teachers know this and can they and do they apply this knowledge?" And we complicate the answer to this question by considering the changing world in which science teaching must occur through a look at demographic projections, especially in urban schools, where these trends are already apparent.

At the risk of destroying the suspense, we can say with some degree of certainty that elementary teachers generally do not know enough to teach science well. Their knowledge about learning and science is limited, if observations of their teaching are any indication. Consequently, the chapters in this report discuss the implications for the preparation of teachers, provision for their ongoing learning and support, and the organizational policies and practices -- at levels from classroom to federal government -- that are needed to promote good science teaching.

For each area of interest, our report considers what currently exists, how it ought to be, and what steps might be taken to get there. Our discussion is based on data from research and sound practice, and from proposals from many quarters calling for future change. Since some visions for the future are discounted as idealistic and impractical, we have tried to base ours on what is possible, citing instances where such practices are already being used. We have also tried to create recommendations that can be implemented either all at once or in stages. Thus those who have the readiness and the resources to undertake major changes have some guidance to do so; those who need to move a step at a time, for whatever reason, can also do so.

What Is Good Science Teaching?

If the task is to achieve good science learning for our country's elementary school children, then let's shift back to Ms. Lopez's classroom, where we think good science teaching is occurring. This scenario illustrates optimal curriculum and instructional strategies for elementary school, discussed in depth by our Center's report on curriculum and instruction (Bybee et al., 1989). The report recommends that the elementary school science curriculum incorporate nine major concepts -- powerful explanatory constructs that are applicable to science and technology and that accommodate different developmental levels. These concepts, with some teaching examples, are:

1. Organization (or orderliness) -- understanding of organizations such as hierarchies, simple-to-complex arrays, and symmetry. Some teaching examples at the primary level are sorting objects or identifying groups of similar animals or plants; at the intermediate level, recognizing interaction within and among the atmosphere, hydrosphere, lithosphere, and ecosphere.

2. Causality -- the search for explanations and links between causes and effects. Some teaching examples are growing plants and determining what factors optimize growth, and exploring health risks.

3. Systems -- understanding how matter, energy, and information move about from reservoir to reservoir through carefully delimited pathways. Some teaching

examples are exploring different body systems and describing whole systems such as toys and machines.

4. Scale -- understanding the quantitative variations of matter and energy, both in a relative and absolute sense. Some teaching examples are drawing simple objects in perspective, recognizing the differences in children and adults, and mapping a small area.

5. Models -- understanding the essential character of phenomena of interest through physical, verbal, or mathematical representations. Some teaching examples are constructing a graph and differentiating between a model and reality.

6. Change -- understanding the nature of change as explanations of phenomena in the natural and artificial world. Some teaching examples are identifying different seasons, describing different life cycles, and naming the stages of development.

7. Structure and Function -- understanding the relationship between the way organisms and objects look (feel, smell, sound, taste) and the things they do. Some teaching examples are describing the structure of an animal or plant, designing a common object, and recognizing the relationship of structure and function in humans, buildings, and environments.

8. Discontinuous and Continuous Properties (Variations) -- understanding the distinctive properties of organisms and objects, and the variations among them. Some teaching examples are describing different tones of colors and analyzing a graph of heights within the class.

9. Diversity -- understanding the different types of objects and organisms and the importance of maintaining ecological diversity. Some teaching examples are developing a simple classification system and investigating a simple ecosystem to identify the diversity of organisms.

In the scenario above, Ms. Lopez chose her seeds unit to incorporate many of these organizing concepts of science. She used instructional strategies that form a four-stage learning sequence. They first -- 1) invite the students' participation. Students then have opportunities to 2) explore, discover, create and 3) propose explanations and solutions. They can then 4) take action to apply their new learnings. This sequence is grounded in research on how children learn science. This research comes from several fields of psychology, among them cognitive, social, developmental, and behavioral, and has recently been brought together and applied to school settings (Champagne, 1987; Resnick, 1983).

Cognitive psychology has contributed to major ideas in science learning. First, in studies of the ways experts solve problems, researchers have discovered that the knowledge and mental processes that they call upon are quite complex. Their knowledge bases, built over time, allow them to see patterns and relationships so they can generate efficient solutions. Furthermore, the research points out that experts are not explicitly aware of the knowledge or thinking strategies that they use. These two points imply that (1) learners need a large amount of experience and information to understand new concepts and apply them in new situations, thus phenomena must be pursued in depth if learning is to occur; and (2) lectures are often not the most effective ways of teaching, since much of the knowledge experts have is tacit, they know too much to tell, and most are not aware of all that needs to be told (Champagne, 1987).

Another line of research indicates that learning for novices and experts alike depends in large part on what the individual already knows. As the knowledge base becomes stronger, the amount that can be learned per unit of time increases (Ausabel, 1968).

Yet another line of cognitive research -- constructivist theory -- demonstrates that children often come to school with a set of deeply held conceptions about how the natural world works (Helm & Novak, 1983). Sometimes these views form a strong foundation upon which new and elaborated concepts can be built. At other times the child's conception is an alternative to scientific principles. Learning can only occur when the child becomes aware of the inconsistencies or unsatisfactory nature of his or her prior conceptions of the world and is helped to either abandon or reconstruct these conceptions. Clearly then, teaching is not as easy as delivering new information. Rather, it takes patient elucidation over time, sometimes long period of time, with opportunities for students to surface their self-constructed theories and test them against evidence. When that evidence illustrates that the world differs from their beliefs, they need time and many more experiences which encourage them to make connections and to construct new meanings. The kind of classroom in which this can be done resembles that of Ms. Lopez: it is flexible, encourages inquiry, exploration, testing of ideas, and risk taking (Harlan, 1985).

Social interaction is a critical part of this learning environment, although it is not at all clear how it contributes to learning. While Piaget's perspective attributes concept development to interactions with the physical world, some social psychologists see social interactions as a more powerful influence on cognitive growth. As Day, French and Hall (1985:51) point out, "Cognitive abilities are (1) socially transmitted, (2) socially constrained, (3) socially nurtured, and (4) socially encouraged." Extensive classroom research by the Johnsons (1987) and Slavin (1988) does not take an either/or stance, but rather points out the key role social processing of information plays in learning. For them, the optimal classroom environment is one where active participation by students is ensured through well structured and continuous interaction with each other and with their teacher.

Another field of psychology that contributes to our understanding of science learning and teaching is often forgotten in light of the new research. Behavioral psychology suggests that skill development -- such as the development of higher order thinking skills like learning-to-learn, problem solving, and scientific inquiry -- best occurs in an environment where students can exhibit the desired skills and where performance of the skills is refined by feedback from the teacher and peers. Student behaviors that approximate desirable behavior are rewarded. This common principle from behavioral learning theory has an important contribution to make to science concept and skill learning (Champagne, 1987).

The four-stage teaching model, exemplified in Ms. Lopez's classroom and discussed at length in our Center's Curriculum and Instruction report (Bybee et al., 1989), is derived from these sources of psychology research. Teachers first invite students to learn, creating opportunities for them to experience new phenomena, connecting them to what they already know, and encouraging them to confront and articulate their own conceptions of how those phenomena work. Students then explore, discover and create, experimenting with the phenomena in greater depth; they then create explanations -- often using language and mathematics -- for what they observe. These explanations are enhanced through introduction of science content, including factual knowledge and ways to do and think about things, and the incorporation of this knowledge into students' own conceptions of the phenomena. Finally, the students take action: using their new understandings and applying them to the world around them.

Like Ms. Lopez, good elementary science teachers create environments that nurture this kind of learning with content which incorporates the organizing principles described earlier. But before turning to more in-depth discussion of how this kind of teaching can become the norm rather than the exception, let us consider briefly the changing context within which Ms. Lopez and her peers will have to work. What are changes in the world that our discussion of good science teachers will need to incorporate?

Changing Settings for Science Teaching

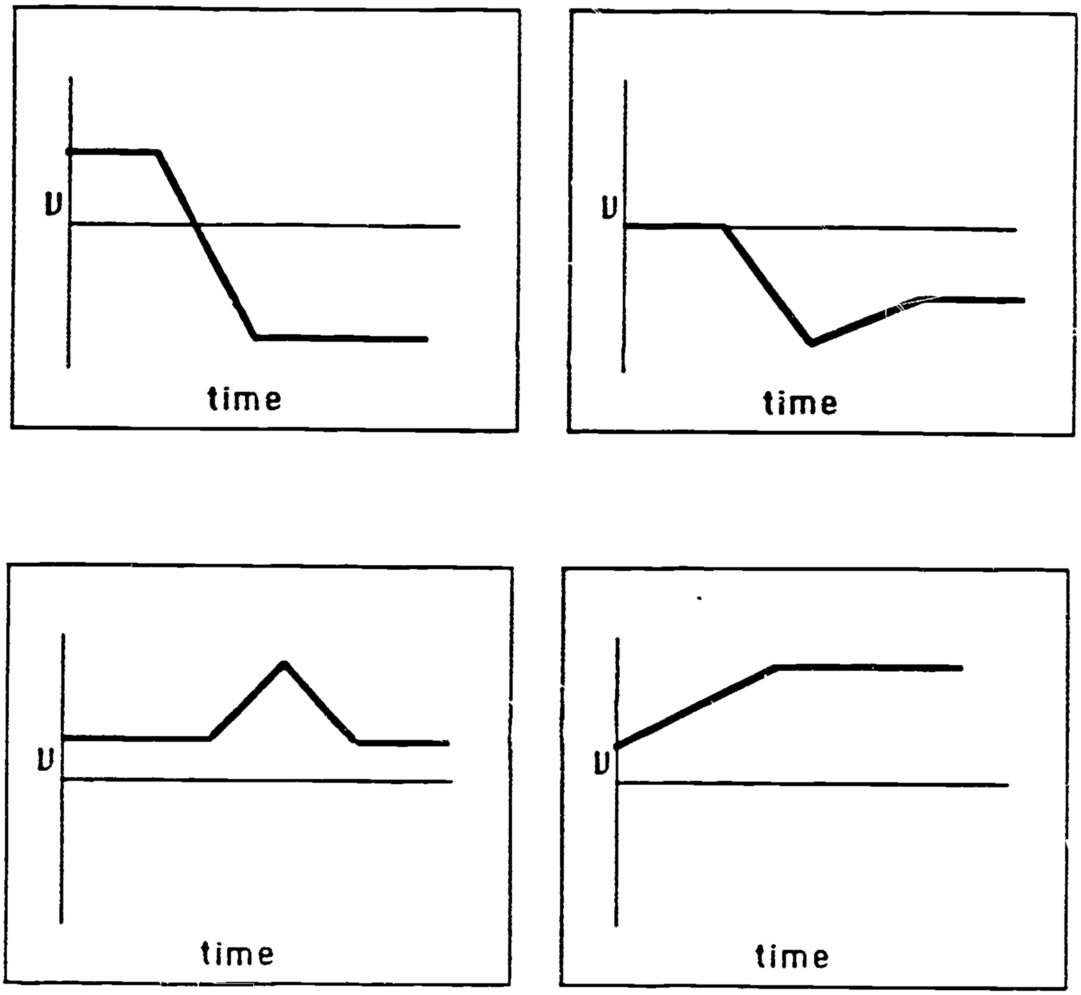
Any report that makes recommendations for the future must incorporate information on future trends. Two important trends deserve mention in a report on education and, in particular, science education. One is the promise of technology for providing educators with tools that can transform the nature of teaching by creating environments that readily promote higher level thinking in children and simulate scientific phenomena that previously could only be described in the abstract. It is impossible -- and, more important, irresponsible -- to ignore this potential in efforts to improve science teaching. The second trend is in demographic projections that portend a dramatic change in the student population our public schools serve.

The Promise and Challenge of Technology

There are many who would argue that current research in cognitive science, coupled with advances in computer technology (both hardware and software), are likely to extend the content we are able to teach in elementary science. Moreover, technology is likely to make it possible to teach many concepts to children at earlier ages than now thought possible. An example describes the marriage of cognitive science and computer technology for teaching.

> *This example is drawn from a project, aimed at teaching sixth grade children how to read graphs (Mokros & Tinker, 1987). That this is a difficult subject has been amply documented by cognitive scientists, who have succeeded in demonstrating that most high school students are incapable of reading and interpreting any but the most straightforward information presented in graphical form.*
>
> *The graphs in question were of position and velocity (and even, at times, acceleration) versus time and were created by moving an object (typically the students themselves) with respect to a distance measuring device (the autofocus from a Polaroid camera) that was connected to a computer. Special-purpose software was then used to construct a graph of the motion on the computer screen in real time. Thus, for example, if the student remained motionless a graph of his or her position versus time would simply be a straight line parallel to the X axis and located at a Y position corresponding to his or her distance from the computer. A graph of the student's velocity with respect to time would, of course, be a horizontal line along the X axis (i.e., at Y = 0). If the student were to walk toward the computer at a constant rate of speed, the graph of his or her position vs. time would be a straight line sloping downward, whereas the velocity graph would still be a horizontal line, but this time located below the X axis. More complicated graphs can easily be drawn by having the student change his or her state of motion during the time (approximately 20 seconds) that the graph is being drawn.*
>
> *This system has been used successfully with sixth grade children in a curriculum segment lasting no more than a week. A typical activity consists of having the students pair up, one student acting as the dancer and the other as the choreographer. Each team of students is given a drawing of a graph that they are to produce. They first confer to try to determine what sequence of motions will be required to produce the desired outcomes. The dancer than stands in front of the computer and moves back and forth according to directions from the choreographer. Both students are able to see the coordinates of the graph as they change on the computer screen. If it does not match what they are trying for, they may simply erase the graph and try again. When they are satisfied with their production they may obtain a hard copy of it.*
>
> *At the end of a week of such activities, with appropriate teacher intervention, the students were successful on a test requiring deep understanding of both position and velocity graphs. For example, one of the questions on the test was:*

Which of the following velocity/time graphs depicts a situation in which the student changed direction?



This example has significant implications for teacher behavior and therefore preparation and professional development. The activities are open-ended and are directed at affecting the way students think about science content (White & Horwitz, 1988).

Raizen (1988) has argued that, in addition to creating these kinds of new learning opportunities for students, computers and associated technology can:

- Remove computational barriers by recording data and performing arithmetic and algebraic operations on them. Computers can also retrieve information from large data bases, allowing real data to be used in science problems rather than having to be artificially constructed. This eliminates the need to both gather experimental data and do time-consuming mathematics operations (Linn, et al., 1987).

- Help teachers to individualize instruction by taking into account what an individual student already knows and the most suitable pace and learning method for him or her (Gallagher, 1983). Computers can give immediate feedback to both student and teacher and monitor student progress.

- Motivate students, especially those at-risk, to learn. Computers allow students to repeat sequences again and again or change the approach, or skip material they already know. When a student can control the pace of instruction without receiving negative feedback that is often emotionally charged, learning is stimulated more effectively (Kulik et al., 1983)

- Enhance the professionalism of teachers. When computers take over time-consuming record-keeping and individualized instruction tasks, teachers are free to engage students in hands-on exploration, confer with them one-on-one or in small groups, and conduct other more situation-specific activities that call on their own creativity and special talents.

Computers and other technologies open up a wide range of choices of how learning can occur and can enhance collaboration among individuals of different competencies (Cole & Griffin, 1987). The community can be linked with the school through out-of-school learning sites; experts from institutions of higher education or industry can be connected to the classroom or directly to the learner; and schools and individual learners can be connected to each other. Teachers can benefit from new access to each other's best ideas as well as those of scientists and science educators.

While the prospects of technology use for the future are promising, the challenge of using the advances in ways that enhance learning are many. For example, although activities such as the example given earlier would be tempting to incorporate into science instruction, it is very important that they not make a curriculum piecemeal rather than coherent and comprehensive. To make good decisions, teachers need to understand clearly what science knowledge and processes different applications of technology can promote. Technological tools need to be incorporated into their own knowledge base, becoming a formal part of their preparation and career-long development sequence. Technology may ease some of the tasks of teaching, as noted above in its individualizing and record-keeping applications. But its use will further complicate the careful decision making that makes science instruction a challenge by creating more options -- and ones highly motivating and therefore also potentially distracting to both students and teachers -- that need to be incorporated into a systematic, comprehensive approach to science teaching and learning.

Demographic Projections and Urban Schools

The second trend that must be considered in a report that makes recommendations for the future is demographic. Simply stated, the population of our schools is changing rapidly and will continue to. As a consequence, schools of the future will have:

- more children entering from poverty and single-parent households
- more children from minority and linguistically different backgrounds
- more children with physical or emotional handicaps
- more children who were premature babies, often of teenage mothers, leading to more learning difficulties in school
- more children with working mothers (McCune, 1986).

While these trends indicate that the populations of many schools will change significantly in the next ten years, today's urban schools already serve these populations. And few would argue that while our urban schools are not meeting their students' educational needs in general, their ability to help students learn science seems especially limited (Mullis & Jenkins, 1988). The very small number of minorities that work in scientific fields further suggests that we are failing to meet the educational needs of minority populations with respect to science.

For this report to be useful for the future, its recommendations must be applicable to our current at-risk populations.

Atkin and Raizen (1988:1) view the central challenge of meeting the educational needs of at-risk students as "figuring out what it takes to draw them seriously into schoolwork." While other students often have successful role models, parents and jobs that motivate them to do what is required, education is not a priority for most at-risk students. "Like everyone else," note Atkin and Raizen (1988:1), "at-risk students have low tolerance for activities that are intrinsically uninteresting and for which they see no purpose."

Research and experience suggest that many of the specific strategies ider 'fied in this report and in our Center's Curriculum and Instruction report as good science teaching are precisely those that enhance learning for at-risk students (Bybee et al., 1989; Mortimore et al., 1988). The content and instructional strategies appropri' : for such settings are those described earlier, with even more attention to:

- content which is either culture-free, or draws on the urban environment and relates to the daily lives of students outside of school
- content which provides a view of the field of science as more than a white, male domain through role models, biographies, and historical perspectives
- content which uses resources outside the school, such as museums, zoos, gardens, hospitals to enrich and expand students' experiences, particularly since they are less likely to encounter such informal learning opportunities outside of school than are middle class students (Beane, 1985)
- approaches that use science content as a vehicle for teaching language and applied mathematics skills, and encourage a wide range of higher order thinking
- cooperative learning strategies, which have significant impact on the achievement, motivation, and social skills of minority and poor students (Slavin, 1988)
- experiential and inquiry-based instruction, which has impact on cognitive growth, student academic self concepts, their sense of fate control, and the internalizing of locus of control (Beane, 1985; Bredderman, 1982)
- sensitivity to cultural differences between the teacher and students which result in different ways of viewing the natural world and of approaching learning -- both of which must influence the environment in which science learning occurs.

Inner city children, like those in tomorrow's schools, have fewer opportunities to learn science -- through trips to exhibits and museums, reading, and interactions with scientifically literate adults -- than do the more advantaged children. Thus the consequences of not learning science in school are more serious. The kind of science teaching occurring in Ms. Lopez's classroom must become commonplace for all children, for it has all the characteristics of the list above.

Other Trends to Consider

In addition to the challenges of technology and changing school populations, tomorrow's elementary school teachers will have to contend with changes in the very nature of science. The last decade has seen large changes in how science is being done, both its processes and its increasingly interdisciplinary nature. In addition, the impact of science on society and the nature of science as a human activity has been the source of much consideration and dialogue (Bybee, 1988; Yager, 1984). As our Center's Curriculum and Instruction report points out, technology has become inseparable from science as one considers our changing world and applying our knowledge to its problems and needs.

These trends and those discussed earlier are certain to tax the knowledge, abilities and flexibility of even teachers like Ms. Lopez, and have important implications for teacher preparation and opportunities for their ongoing development.

Teacher Knowledge and Skills

Do elementary school teachers currently know what they need to teach science? Lacking an appropriate measure of teacher knowledge (Murnane & Raizen, 1988), we have only random indicators that, in fact, many elementary school teachers may lack such knowledge. The indicators include:

- Survey data on science courses taken in college. The National Science Teachers Association standards recommend one course each in biology, physics, and earth science. Only 31% of K-3 teachers and 42% of the 4-6 teachers meet these standards (Weiss, 1987).

- State course requirements. Fewer than half the states require elementary teachers to take a course in science methods (Blank & Espenshade, 1987).

- Self-reported adequacy to teach science. A 1985-86 survey indicates that, while 82% of elementary teachers judge themselves well qualified to teach reading, 27% feel the same way about their qualifications to teach life science, and only 15% feel qualified to teach either physical or earth/space science (Weiss, 1987).

- Classroom behavior. Although teachers report that they use strategies of inquiry and stress higher order thinking and concept development, research studies repeatedly show their teaching to be characterized as lecture, with some discussion, stressing factual learning (Goodlad, 1984).

In his observation of the science teaching of both pre- and in-service elementary teachers, Arons (1983:113) notes that

> the majority use concrete rather than formal patterns of reasoning; they cannot do arithmetical reasoning involving division. . ., do not control variables; they cannot visualize possible outcomes of changes imposed on a system; their "knowledge" of science resides exclusively in memorized names and technical terms, and because they lack adequate operational understanding of these names and terms, they are unable to reason with them in any specific instance.

Thus from a scan of teachers' coursework, their classroom behavior, observations of their work with science concepts, and their own self report, it appears that many elementary teachers have significant gaps in what is needed to teach science. They do not know science content, so have limited ability to apply or reason with basic scientific principles. Nor do they know the strategies and approaches required to teach science well.

Before turning to ways teachers can be better prepared and supported to teach science well, it is well to ask the question, "what *should* teachers know and be able to do?" The recent explosion of knowledge about learning and concept development requires us to answer this question directly, since merely turning back to the indicators mentioned earlier and requiring (1) more college science courses and science methods courses, and (2) less frontal teaching and emphasis on factual learning will not provide sufficient guidance.

Teachers need to know both science content and pedagogy to teach science well. As Shulman (1986) argues, it is not enough to have good generic teaching skills; rather, each discipline requires its own teaching strategies. Teachers' content knowledge as well as their "pedagogical content knowledge" are both of concern.

Anderson (1987) responds to this question of teacher pedagogical knowledge in science by portraying what he calls "strategic teaching". Incorporating his view with our earlier discussion of good science teaching, we believe that a teacher needs to know:

- that science is more than a set of facts, rules, and definitions, and even more than these plus process skills; rather, it is an attempt to describe, explain, and appreciate the natural world;

- basic principles of learning and teaching that guide her or him to teach for understanding;

- that teaching for conceptual change or development requires a preparation phase, where students are invited to learn by tapping their own experiences, arousing their interest and excitement, and engaging their real world as a way of assessing their prior knowledge; a presentation phase, where students are given opportunities to explore, challenge, enhance or reconstruct their own conceptions; and an application phase, where students take action, using their new knowledge by testing its value in a variety of ways;

- how to assemble and/or reconstruct print materials and activities so that they emphasize scientific theories and principles to explain the phenomena in the natural world and help students explore and construct new understandings;

- the major principles and theories of life and physical science or enough understanding of these bodies of knowledge to know where to go when more information is needed; and

- how to create an environment in which each student is engaged in activities, with sources of authority, and in communication with other students and the teacher for the expressed purpose of conceptual development.

The remainder of this report suggests an approach to helping elementary school teachers develop the knowledge, skills and routines they need to teach science well.

CHAPTER II. TEACHER DEVELOPMENT

Introduction

If, by objective measures and by their own admission, teachers don't know much about science and science teaching, then their initial and ongoing development takes on enormous importance. What does it look like now, and how must it change to promote a vision of effective science teaching?

Currently, an individual may teach elementary school having had no or very little opportunity to learn science or science teaching. This is true of those preparing to teach and those presently teaching. University, state, and district requirements are so varied that the current low levels of knowledge and skills are not surprising.

What we refer to as "teacher development" -- conscious attempts to help teachers or prospective teachers learn what they need to know -- presently is compartmentalized, occurring in distinct stages. These stages typically include science coursework; professional education coursework; clinical experiences; and inservice education. What is taught at each stage is the responsibility of different people and institutions (e.g., liberal arts and sciences faculty, teacher education faculty, district staff developers and/or curriculum coordinators). There is rarely coherence or continuity across stages and responsible parties. As a consequence, there is no one institution or formal collection of institutions responsible for ensuring that teachers have the science and science teaching knowledge they need· this is left to the individual elementary school teacher who may be (and probably is) more interested in language development and is least likely to understand the implications of under-preparation in science. In addition, the processes by which teachers are taught vary from a more "knowledge delivery" mode (e.g., science coursework), to a pure modeling mode (e.g., student teaching). Some stages combine learning processes, for example, in a professional education course or an inservice workshop, teachers may be given new knowledge, which they then observe in use, then practice themselves. But the acquisition of new knowledge and its application to teaching are most often separated.

Finally, it is assumed that teachers are capable of taking full responsibility for the classroom when they are certified to teach. This is typically at the end of their preservice preparation.

Because teacher development efforts have traditionally had these characteristics, few teachers are prepared to teach students well at the time they become fully responsible for a class. The beginning teacher attrition rate is enormous. Further, once they are hired as teachers, their continued professional development is largely learning by doing. The more formal opportunities for learning are ones they select from a smorgasbord and experience as individuals. They are either short-term and largely practical or long-term and largely theoretical. They are rarely part of any long-term development effort.

While the current approach to teacher development is problematic for teachers in general, the consequences for developing good elementary school science teachers are most dismal. Science coursework is limited; professional education courses include, at best, one course in science pedagogy; only coincidentally does a clinical experience occur with a model science teacher; and inservice offerings in science are most often attended by teachers already skilled in science teaching.

Although the last several years have seen renewed efforts to improve teacher education in general, we believe that a new approach is needed to improve the capabilities of elementary teachers for science teaching. At a general level, this approach does not differentiate science teacher training from the development of elementary teachers as a whole. As the report progresses we indicate areas particularly relating to science. We should also note that our current discussion is of the preparation of *all* teachers to teach science. A discussion of science specialists appears later, although, even when specialists are used, regular teachers need a basic understanding of science teaching and of ways to integrate science into their own responsibilities.

The approach we propose has five characteristics. First, teacher development needs to be viewed as on a continuum rather than in distinct stages. The continuum includes what is now undergraduate preparation, continues through a period of induction where responsibility for students is assumed gradually, and incorporates the remainder of the teaching career. Over this extended period of time the teacher learns and renews what he or she needs to provide optimal science learning for students.

Second, the process of teacher development should incorporate a theory of learning that mirrors that of student learning. We noted in the previous chapter the constructivist views on learning. Like all learners, teachers need to construct their own knowledge and theory of science learning that is developmental and that is based on experience, reflection, interaction with others, and exposure to effective teaching models. This means that current teaching strategies must change, from science coursework through inservice opportunities.

Third, there should be much more overlap between campus and field instruction in teacher development, with a gradual shift of primary responsibility to the field. As teachers require more and more exposure to and interaction with children to foster their learning, their time is spent less within the walls of the university and more in the schools. As their need increases for strategies to teach, they need more and more to be under the tutelage of expert teachers of elementary school children, and less of university faculty. This transition should not be abrupt, but rather a gradual shift. Thus the difference between what has previously been called preservice and inservice is more a change in support structures than in content or process.

Fourth, collaboration between and among the various organizations involved in teacher development (e.g., the university faculties, school districts, state certification agencies, teachers' associations) is no longer an option, but a requirement. Teacher development needs to be a joint responsibility. Not only do they need to have close working relationships with clear understandings of how responsibilities will be shared, but they need to change simultaneously, since the success of a change made by one part of the system will likely rest on a change made in another.

Finally, the development and ongoing support of teachers needs to exemplify a norm of continuous learning. The vision of schools as learning communities fo both the adults and children within them can only be supported if teachers believe that they themselves are learners. The best kind of teacher development helps teachers live this norm so that they can model it for their children.

The Need for Experiential Learning

Experiential learning is the key to teacher development approaches with these characteristics. Creating opportunities and environments in which it can occur requires understanding and attending to the developmental nature of teachers' knowledge, skills and feelings. Learning research suggests that, without an experience base upon which to develop personal meanings, concepts and principles are not learned. This is true for learning science, learning about learning, and learning about teaching Providing opportunities to develop, elaborate, and sometimes change, prospective teachers' personal meanings for concepts of science, learning, and teaching is the primary challenge for teacher educators at all stages.

Teachers develop affectively as well as cognitively, and experiential learning approaches attend to these needs as well. Fuller's (1969) research indicates that prospective teachers develop in their concerns about teaching from very self-related issues, to concerns about how to get the task of teaching done most effectively, and finally to concerns about how their students are faring. The implication of this research is that, as individuals approach, begin, and continue their teaching careers, they need opportunities to resolve their earlier concerns so that later ones can emerge. To do so they need many earlier and different kinds of experiences with materials and in settings such as schools and classrooms so they can feel increasingly more comfortable and more competent with content and with the challenges of teaching.

Thus both cognitive and psychological research undergird the need for experiential learning opportunities at every stage of teacher development. In science courses this means investigating phenomena much as scientists do. In child development and learning courses it means spending time observing and working one-on-one with children. And in the study of pedagogy, it means a considerable amount of time spent in school settings.

The implications of this argument call for fairly substantial change in methodology, in setting, and in approach throughout the teacher preparation and inservice sequence.

The Phases of Teacher Development

While we are committed to much greater coherence and connection among the components of a teacher development sequence, there nonetheless appear to be phases of development that have distinguishing characteristics. In the early phase teachers are typically students in universities. Their primary aims during this phase should be developing a strong background in the liberal arts and an understanding of children and their development. In the middle phase the emphasis is on teaching. Here the aim is to develop and practice the knowledge and skills needed to teach a class of children in a competent and comfortable way. Finally, the later phase involves experienced teachers in the updating and renewal of their capabilities to teach children and assume other educational responsibilities as well.

We think that the time spent in each phase should and will vary. This is partly because teacher development is a process that, if done in an optimal way, should be flexible, depending on the needs and progress of the individual teacher. So a given program should have its own flexibility. Further, there are currently a number of different scenarios being proposed and tested for the development of teachers, and there are as yet no strong data to support the strength of any one scenario over any other. For example, there are those who argue for a four-year liberal arts degree before beginning the professional sequence (Carnegie Forum, 1986). Others argue for programs lasting five or more years which incorporate a liberal arts degree, professional certification, and often a masters degree as well (Holmes Group, 1986). Half-year and full-year internships are both common, as are one- and two-year induction programs. In addition, alternative certification programs are preparing people with bachelor degrees and work experience to teach through various approaches, including intensive summer institutes and/or after-school seminars.

Our vision of an optimal teacher development sequence, while flexible, does have some parameters. It makes sense that an early development phase that focuses on liberal arts and child development should take between three and four years. The middle phase with teaching as its focus should have one to two years with full supervision (i.e., before certification) and one to two years of support once hired, even provisionally, as a teacher. Thus our vision ranges from a time allocation that is fairly traditional (i.e, four years undergraduate, but with at least one year of supported induction for the first year teacher) to the more extreme vision of a five-year professional sequence plus two additional years of supported induction.

We do not support the call for an abbreviated preparation period for elementary science teachers; the reason will be clear in our discussion of what needs to be in a program. There is simply too much that teachers of elementary school science need to know to make non-teachers into teachers overnight, regardless of their qualifications. We also doubt the efficacy of a program that has all of what would traditionally be known as "teacher education" in a single [fifth] year. This is for the same reason: there is simply too much to learn.

The actual choice of how many years should be invested in the early and middle phases of teacher development should depend on (1) evidence from the current experiments, (2) the resources available, and (3) the background and qualifications of the individual.

We believe that these are the characteristics of good elementary school teacher development programs. But where does science come in? First, through a teacher development program that gives science the emphasis it deserves in elementary education, i.e., puts it on equal footing with language and mathematics. Since neither teachers nor districts give high priority to science (Bybee et al., 1989), teacher development efforts need to ensure that elementary teachers are grounded in not only the knowledge and skills needed to teach science, but the conviction of its importance as a basic.

In actuality, elementary schools have two clear options for promoting science learning. One is to have every teacher prepared and then continually supported to teach science. Another is the use of science specialists, where fewer teachers know and can teach science, and do so for all students in the school, while other teachers specialize in other subjects. This option is discussed in greater length in Chapter III, since it is an organizational issue. In this chapter we simply note that this appears to be a viable option for later elementary grades, and we discuss implications for the development of such specialists at a later point.

Early Phase of Teacher Development:
Learning about Science and Children

We would argue that, given what elementary teachers need to know and be able to do to teach science, this early phase should include:

- a major in a discipline, although not necessarily science;
- coursework in one or more sciences that allows teachers to experience science the way it ought to be taught; and
- an introduction to child learning and development that is simultaneously experiential and theory-based, and to the influence of cultural and community differences on learning and teaching.

A Major in a Discipline

One of the problems with many current teacher preparation programs is that teachers major in elementary education, rather than in a discipline. As the report of the Holmes Group (1986:14-15) notes,

> For elementary teachers, this degree has too often become a substitute for learning any academic subject deeply enough to teach it well. These teachers are certified to teach all things to all children. But few of them know much about anything, because they are required to know a little of everything. No wonder so many pupils arrive in high school so weak in so many subjects.

Students majoring in elementary education take courses from a number of disciplines and do not come to understand the nature of a discipline -- its methods, products, relationship to society and to other disciplines. It is then no surprise that, when faced with teaching physical science, for example, they do not understand that there are major principles of physical science that should help them organize their curriculum so that children will develop conceptual understanding. The premise underlying this recommendation is that if a teacher majors in a discipline, i.e., takes a large number of courses that encompass the breadth and depth of a body of knowledge, even if that major is in history or economics, then how to organize the content of science instruction would be more informed (Champagne, personal communication, 4 April 1989).

While there are traditional programs in a major, there are other kinds of programs that achieve the same outcomes.

> *An example from the Carnegie Report (1986) illustrates that such breadth and depth can be more than merely acquiring a large number of credit hours in one subject. Biology majors at Stanford University encounter an interdisciplinary program staffed by professors of law, psychiatry, anthropology, geology, genetics, radiology, chemistry, sociology, and [illegible], to name a few. It differs from other interdisciplinary programs in that it discourages dabbling. Rather, students study a particular field in-depth, apply their knowledge to practical problems, and, during an internship, have an opportunity to contribute to on-going work in the field.*
>
> *Beginning with coursework that exposes them to the central ideas in the natural and social sciences, students then take advanced courses in an area of special interest. Their curriculum is grounded in statistics and the fundamentals of public policy. It provides opportunities for intellectual engagement over time and for testing their knowledge by applying it to real problems or situations.*

One could imagine that an elementary school teacher with such an undergraduate preparation program -- whether or not in a science discipline -- would come to teaching with a rich understanding of learning and a sound respect for knowledge.

Well Presented and Organized Science Content

Our previous point about majoring in *any* discipline did not mean to imply that teachers do not need knowledge of science to teach it well. Indeed, we believe they should have several science courses as part of their undergraduate education. The NSTA recommends one course in each: life, physical and earth science. Others (Champagne, personal communication, 4 April, 1989) recommend at least two courses in one science (biology, chemistry or physics), preferably with exposure to other sciences as well. This is because science is a special kind of discipline, with its own content and ways of thinking. As noted by Anderson and Smith (1987), teachers need answers to the questions: What is special about scientific knowledge? What aspects of scientific thinking are like our common sense thinking? What are different? What are the basic conceptualizations upon which knowledge in a scientific discipline are built?

But do current science courses answer these questions? Typically no. Rather, university science courses organize their discipline around a set of facts and principles, and do not address more epistemological or historical questions such as these.

The implication, then, is that, while teachers need to take courses in science, they are not the courses that are currently being offered (Yager & Penick, in press). As Arons (1983:94) points out:

> To develop a genuine understanding of concepts and theories, the college student, no less than the elementary school child, must engage in intense deductive and inductive mental activity coupled with interpretation of personal observation and experiences. Unfortunately, such activity takes place in only a handful of passive listeners, but it can be enhanced, nurtured, and developed in the majority, provided it is experientially rooted and not too rapidly paced.

The best kind of science courses would:

- teach science in the way that it is practiced, pursuing real questions about the natural world, and incorporating investigative methods with knowledge of the important facts and concepts of the discipline
- be interdisciplinary in that they relate their particular field to related fields (e.g., a chemistry course would bring in physics, math, biology)
- ground the discipline in its philosophical assumptions and historical context
- help students relate the content to societal issues (Champagne, personal communication, 4 April 1989).

A course that had these features would:

- spend relatively more time on fewer concepts than traditional courses, and, as Arons (1983:97) says, "back off, slow up, cover less, and give students a chance to follow and absorb the development of a small number of major scientific ideas at a volume and pace that make their knowledge operative rather than declarative"
- require close collaboration with professors of other disciplines, including those outside the natural sciences (e.g., history and philosophy)
- prepare people with basic facts and principles of the science and some thinking skills so that when they want additional information about the science, they have the necessary data base and skills to access it.

An illustration of such a course is the introductory geology course at Carleton College in Northfield, Minnesota. Its goal is for students to act as scientists and perceive science as a way of behaving rather than as a body of knowledge. A typical textbook introduction to geology would begin with the earth and its place in the solar system, and progress through matter and minerals, rocks, the geologic cycle and geologic time, the evolution of the lithosphere, and geology and industry. Instead of using this textbook orientation, students are given a series of problems that require them to learn about various aspects of geology in order to solve them.

For example, the class might go to a river where several large gullies were apparently caused by erosion. Teams of students attempt to determine what is happening. Then the group convenes to discuss their observations, air their questions, and decide what further observations and information are needed. Back on campus, class meetings focus on gaining more information about the topic. They discuss whose responsibility it is to stop erosion, how it could be stopped, what scientific technology is available to stop it. In this way, knowledge is built and used, applied to the same kind of problems for which students will need science in the future.

Note that this example is not one of a course entitled Science for Non-Science Majors or Science for Elementary Teachers. It describes a fundamental course in a science that is available to all, majors and non-majors alike. It accommodates the criticism of survey courses which emphasize breadth rather than depth in terms of what teachers need to know. As Arons (1983) notes, such courses, which typically attempt to give students an insight into the major achievements of science, have little impact on students. Further, courses with the titles noted above are notorious for their reputations as courses for the less intelligent, and, while in and of themselves they may be intellectually challenging, they lack a broad spectrum of students, some of whom can elevate the level of discourse in the class.

At Alverno College, students participate in an integrated science laboratory that takes a developmental, constructivist approach to helping students learn science principles in depth. Students' initial learning experiences

"focus on observing phenomena and making inferences about mechanics and energy. Those who already know how to make abstract statements relating weight and distance in the balancing of an object are encouraged by the instructor to identify within themselves the process those statements represent, to discover the stages of the process, and to begin to understand how an analytic framework contributes to scientific inquiry.

Those for whom science is territory unexplored, and often threatening, work from a more familiar perception -- like their experience of a teeterboard and how they have made it work by adding the support of another body on one side or moving forward to make it balance. Gradually they establish alternative ways to balance a poised plank. They then discover that what they did by feeling their way, has patterns (indeed laws) of operation that can be formulated, proved, varied, and reapplied. Thus they come to an awareness of the process by a different route, one with many side stops on the way to clarify, incorporate, and try out new knowledge (Loacker et al., 1984:53)."

An Experiential and Theory-Based Introduction to Child Development and the School Context

As noted by Anderson and Smith (1987), teachers are not always aware of the conceptions of the world that children have constructed for themselves, nor, oftentimes, of the fact that children even have these conceptions. While these particular authors have focused their work on developing conceptions of science, sufficient work has been done in other areas, such as language and mathematics, to indicate that there are important commonalities. A course in child learning and development would provide the opportunity for preservice teachers to observe and probe children's conceptions in and across several content areas. They would then learn developmental theory to help explain and put some structure on their observations.

In a similar way, preservice teachers need to be introduced to the contextual factors that make schools the social organizations that they are through experiences that they can then relate to theories and concepts. How are schools organized? How does this organization influence the lives of teachers and children? What influences do community factors such as wealth and values have? What influence does the political environment have? What are various scenarios for change in the organization and structure of schools that seek to optimize the positive influence of these factors?

These learnings about child development and schools as organizations necessarily need to be simultaneously experiential and theory-based for several reasons. First, while there are sound theory bases for both, without experience upon which to develop personal meanings, prospective teachers cannot really learn the concepts and principles. It is important to apply this understanding to the learning of students in a teacher preparation program as well as to the children they are preparing to teach.

While many prospective teachers have spent time with children, they typically have not focused that time on gaining an understanding of how children learn. Further, they have only their own experiences in classrooms, i.e., those of being a student, to provide understandings of the social context of schools. Thus before preservice teachers are introduced to theories of learning and social context they need highly structured opportunities to observe and work directly with children of different ages, within different kinds of activities that promote different kinds of learning; and they need opportunities to explore and probe the environment of schools -- both the internal environments and the communities in which they exist.

Only with this kind of experience base can preservice teachers begin to relate to research on learning and schooling. Theories take on meaning as they provide a useful framework for the students' observations and experiences.

An illustration of such a child development course comes from Wheelock College where a two-semester Human Growth and Development course is complemented by field work in which students spent one-half day a week with children. Guided observations and journals help students articulate the developmental theory learned on campus with observed behavior. Relationships between theoretical and practical knowledge are considered in small tutorial meetings.

To illustrate a course related to the social context of schools,

The University of Houston's Reflective Inquiry Teacher Education (RITE) program helps prospective teachers develop an inquiry approach to their own learning by giving them opportunities to reflect on the environments in which children grow and learn.

This is particularly important in their setting, where an emphasis is placed on preparing students to teach in urban and limited English speaking communities.

In the first hours of their program, students complete detailed community study projects that take them into the residential and business areas surrounding selected Houston area schools. As they complete the tasks within the project, they meet and interview parents, policy workers, librarians, real estate agents, and others. They observe living conditions, recreational opportunities, and identify community support services. These projects stimulate questions about community factors that might affect students' attitudes and performance in school.

A second project focuses on school contexts and their influence on the practice of teaching. Students are introduced to research on effective schools with a particular emphasis on the role of the principal (or other instructional leaders) in creating a climate that is conducive to learning. They examine several classrooms and compare the organizational patterns and the ways teachers manage instructional time. Once again, they are encouraged to raise questions -- this time focusing on school level factors that enhance or diminish a teacher's ability to work with children.

The following excerpt from a student's final project illustrates the awareness of contextual factors:

> *I never gave it much thought that I would be teaching students who don't get three balanced meals and nice, warm clothes in winter... I didn't think of the fact that I might be expected to teach students who couldn't read, write, or speak Engl... I just hope I'm ready for whatever challenge is ahead of me and I hope I'm ready for whatever turn I take (Waxman et al., 1988:4).*

Middle Phase of Teacher Development: Learning About Science Teaching

This phase of teacher development focuses on teaching. It is here that the preservice teacher moves from an understanding of children and their development to the ways a teacher can foster that development within the context of the classroom and the school. For elementary teachers, we include attention to science as a content area. This phase includes:

- development of a repertoire of teaching strategies that apply knowledge of content, including science, and of child learning and development;

- opportunities to practice these teaching strategies with guidance and feedback in situations that gradually change from the more ideal, one-child, low constraint situations to those of the real classroom;

- special attention to content areas, in particular, for the purposes of this report, to science teaching and materials;

- assumption of classroom responsibilities under supervision, also known as student teaching or internship; and

- supported induction activities.

Activities throughout this phase require opportunities for intensive, exemplary experiences in classroom settings where theoretical constructions can be integrated into the real world. Twenty years ago it was typical to keep a student on campus until the last semester of preparation: student teaching. Now it is becoming increasingly common to see a course sequence that incorporates experiences in classrooms from the beginning. We began to do so in the child development course described in the early phase. However, a fully integrated preparation program is far more than periodic opportunities to observe and try out new ideas in classrooms. It is designed conceptually to provide students opportunities to answer the questions of most relevance to them as those questions emerge, to learn conceptual frameworks when their experience base is large enough for such frameworks to be useful, and to see and experience exemplary teaching and learning.

In the middle phase of teacher development preservice teachers integrate and apply their learnings about subject areas including science, children. and schools to creating learning experiences for children. They move from one-on-one experiences that help them feel more comfortable about what children are like, to mastering small group teaching strategies, to taking full and legal responsibility for a classroom of children under the helpful guidance of a mentor.

What kind of a setting can afford such opportunities? Not just any elementary classroom, not in today's schools. This is particularly true in terms of providing models of science teaching and learning. Unfortunately, there are too few Ms. Lopez's. Therefore the concepts of clinical classrooms and professional development schools take on critical importance (Holmes Group, 1986; Schlechty, Ingwerson & Brooks, 1988). These are settings in which the teaching is exemplary and in which there is a commitment to the preparation of teachers as well as children. Teachers in such settings work collaboratively with university teacher educators to formulate and then provide optimal learning settings and experiences for preservice teachers. Clearly this requires close collaboration if the classroom is also to serve the learning needs of the children. Here the study of teaching can best occur.

An example of such a setting is the Devotion School in Brookline, Massachusetts, a collaborative "professional practice school" where teacher preparation is supported by Wheelock College. There, a team of three classroom teachers and one half-time remediation specialist work with three interns -- participants in a masters program at Wheelock. The interns work full-time in classrooms and are included in every facet of the school day. In addition, they take two courses per semester.

Classroom teachers play a major role in training the interns; one teacher has 20% time designated to supervise them and team-teach a graduate student teaching seminar at Wheelock. One reason this program works is because another component of the Devotion School project is team teaching, with the team having control over time and individual teaching assignments. This provides the flexibility to accomplish several goals, including both pupil and teacher learning, with a variety of possible staff roles. It also models for interns the kinds of collegiality and restructured teaching and learning environments that may characterize schools in the future.

Development of a Repertoire of Teaching Strategies

There are two possible scenarios for ' component. They differ in specification of content. In the first, teaching strategi. .re introduced and applied across a variety of content areas. For example, cooperative learning is learned and used to teach science, language and math content. This is based on the assumption that there are some common teaching strategies and some generalizability across content. It requires that the instructor be versed in all content areas and select or help prospective teachers select relevant teaching examples.

In another scenario there would not be treatment of generic teaching strategies. Rather, instructors for each content area would select and teach those strategies most useful to their content, coordinating with others so the prospective teacher experiences some coherence across content area. The argument for this approach is that there is limited transfer of learning across content areas, that certain strategies are more important than others in some content areas, and that strategies need adaptations for different subject areas.

Whichever scenario is chosen, it is important that relevant content be embedded in the development of every teaching strategy. To illustrate, it would not be appropriate to model a cooperative learning strategy, as has been done repeatedly at a well-regarded university, by asking each person to bring his or her favorite recipe for chocolate chip cookies, with the assignment of cooperatively developing a single recipe. A more content-embedded assignment would be to give the group earthworms and ask them to generate questions about the characteristics of living things using the worms and then testing their ideas.

This component of teacher development addresses the question: What is good teaching? Although there is debate about this in some areas, we have defined it for science. While it is tempting to answer this question through a series of training sessions in effective teaching strategies, preservice teachers first need to see exemplary teaching first hand. They need to conduct structured observations of a variety of teaching strategies so they understand what teachers do that results in different kinds of behaviors in their children.

Once preservice teachers have a rich experience base and can recognize good teaching, a training sequence (Joyce & Showers, 1988) can help them develop the knowledge and skills they need to master different strategies. Research on teaching can indeed provide a starting list of strategies useful to teachers for teaching science, including inquiry-based instruction, cooperative learning, questioning techniques, discussion and presentation strategies, classroom organization and management, motivation, and assessment approaches. A discussion of the theory and rationale for the strategies should be followed by a demonstration, either in the classroom or using videotapes. The strategy should be practiced with feedback in a non-classroom setting, then in a classroom with one child or a small group of children, with coaching (Joyce & Showers, 1988). Because the key to good teaching is making appropriate decisions about when and how to use which strategy (Saphier & Gower, 1982), discussions should follow that consider how each strategy might be used.

Special Attention to Science Teaching and Materials

Whether or not the study of teaching strategies focuses exclusively on science, there is need to spend time helping prospective teachers pull together their various learnings in order to walk into a classroom and teach science. Particularly important is the question, "What science do I teach?"

Responding to this question involves helping prospective teachers articulate the goals for science in elementary grades, understanding the issues of content and process, breadth vs. depth, etc. They then can be helped to use the organizing concepts described in our Center's Curriculum and Instruction report and listed in the first chapter of this report to consider the science content and processes learned in their early science courses, so that an appropriate set of learning activities can be designed for children This is not to suggest that prospective teachers will be encouraged to develop all their own materials, but rather to build a framework that guides the selection of materials. They need to see and actually do activities from a variety of sources. For example, existing programs such as SCIS (now available as SCIIS) and ESS have a scope and sequence and hand-on activities that reflect all of the organizing concepts. Activities from these programs, in addition to those from other NSF-funded curricula of the past two decades, have been collected, indexed, and captured on the CD-ROM Science Helper, currently under development by Mary Budd Rowe at the University of Florida, with support from the National Science Foundation. Prospective teachers can also explore the elementary science programs that are in the National Diffusion Network, such as Life Lab and FAST (Lewis, 1988), and those district programs described in the NSTA's Focus on Excellence (Penick, 1983; Penick & Bame, 1988). Also, the newly funded NSF elementary science curricula offer teachers new approaches to science education that incorporate a "hands-on, minds-on" dimension with technology and connections to society (Bybee, 1988). While still in their development stages, these programs' formats, approaches, and materials form useful study material for science teachers.

Prospective teachers also need to review popular textbooks and analyze how they can best be used. Finally, the issues of science assessment and alternative strategies for use in the classroom, most often ignored at both preservice and inservice levels, need to be discussed and tried out (see Raizen et al., 1989, our Center's report on assessment of science learning, for useful references and resources).

Developing an understanding of the goals of elementary school science, science curriculum scope and sequence, the integration of science process and content in designing activities, the use of the teaching strategies developed earlier within these activities, the availability and use of alternative approaches to science assessment -- this provides a strong foundation for science teaching. Prospective teachers need opportunities to observe and analyze science lessons; try some activities with one or two children; and finally develop and teach science units, followed by feedback. An example of an approach that helps them develop their own understandings from their varied experiences follows.

> *Such an approach is taken by the University of Northern Colorado's model program in science and mathematics for elementary preservice teachers. Integrating coursework in science and math content, and science and math teaching methods, the program has a constructivist orientation, influenced strongly by the work of Piaget and more recent cognitive psychologists. If children build their own mathematical and scientific notions, then teachers must know how to link instruction with learners' developmental processes. They learn about maturation, physical and logical experience, social interchange, and reconciliation of contradictions and the roles they play in elementary school science and mathematics.*
>
> *The science and mathematics methods courses are coordinated so that mathematical skills, critical thinking, and problem solving in science are integrated. This also links mathematics to science, technology, and society.*
>
> *A central design feature of the project is that effective teaching strategies (such as inquiry techniques, use of a modified learning cycle, and hands-on activities) are used to teach the project's science and mathematics content courses. In the methods courses the students reflect on and analyze these strategies, which provide a common base from which methods topics are developed and extended.*
>
> *The methods courses emphasize inquiry, questioning strategies, cooperative learning, classroom management skills, and appropriate evaluative measures for inquiry/discovery learning. Gender, minority, and special education issues are directly addressed, as are concerns about student attitudes toward science and mathematics*

learning. Approximately 30% of student time in science and mathematics methods classes is devoted to observations and activities in schools.

Science methods course students teach selected lessons from elementary programs, including K-6 materials under development by BSCS. Using these lessons as models, students then develop their own and teach them in K-6 classrooms of cooperating local schools, in the UNC Laboratory School, and in UNC class sessions (Heikkinen & McDevitt, 1987).

Assumption of Classroom Responsibilities, with Supervision

This component of teacher development is alternately referred to as student teaching and as an internship, although some see the latter as necessarily longer and offering more in-depth opportunities for teaching practice. During this semester or year-long experience, two features are critical: the gradual assumption of increasingly more classroom responsibilities, with intense coaching; and a placement where exemplary practice is continually modeled and discussed. The difference between the typical student teaching experience and the one envisioned is that, while traditional student teaching has emphasized modeling and mimicking, a more effective form adds thoughtful trial, examination and interaction around the experience. And, for the purposes of this report, the experience gives sufficient attention to science teaching.

The first feature has traditionally been part of student teaching, although the nature and intensity of coaching have varied widely. Prospective teachers need opportunities to try out their knowledge and skills, beginning with low-risk, fairly uncomplicated assignments with few children (although these may be dispensed with if such field experiences have preceded student teaching), and finally experiencing full-day, full-time teaching assignments. A university supervisor partnering with cooperating teachers can provide an important link between earlier learnings and current teaching assignments through such vehicles as weekly seminars.

To illustrate, Wynn (1988) describes weekly three-hour seminars at Florida Southern College that provide support for teacher interns. The seminars are structured to address interns' concerns as they experiment with teaching strategies and materials. They videotape lessons, are coached in the seminars by their peers, and keep journals of their experiences.

The second feature critical to a successful internship is the opportunity to work with and observe an exemplary, supportive teacher. It is well known that teachers look back on their student teaching as the most important experience in their preparation program (Lortie, 1975); further, student teachers model their teaching after the cooperating teachers. Because this is such a key experience, it is imperative that elementary interns observe and discuss good science teaching with someone who both does it well and is committed to it. Otherwise, they are unlikely to teach science well when they become teachers.

Cooperating teachers must not only demonstrate good science teaching, they must also be able to articulate what they are doing and provide appropriate supervision to the intern. This requires training, since good teachers of children are not always good teachers of adults. Training in clinical supervision enhances a cooperating teacher's ability to communicate what good teaching is and how an intern can improve.

> *To illustrate, the University of New Hampshire, in collaboration with the neighboring school districts, provides special training to teachers who supervise their fifth year interns. Teachers learn about the stages of adult development, develop skills in a number of supervision strategies and then practice matching the strategy to the stage(s) of development of their interns. This approach encourages teachers to be both thoughtful and systematic in their interactions with interns, resulting in a far more intense learning experience for both intern and cooperating teacher (Oja, 1988).*

<u>Supported Induction Activities</u>

The first year of teaching is the most difficult, due, in large part, to the assumption that certification as a teacher brings with it mastery of all the tasks of teaching. Rarely is that assumption true today. But it would likely not even be true if the experiences which have preceded it are like those we have described in this section. Teaching, especially elementary teaching, is simply too complicated, and every school is a new organizational setting that needs to be understood and reckoned with.

As educators recognize these issues, induction programs are becoming more common. Twenty-two states have recently instituted induction programs for beginning teachers

(Capper, 1988), and even where they are not mandated, many school districts are developing them.

Good induction programs have:

1. Well chosen, well trained mentor teachers who are both models of good teaching and supportive adults, the same characteristics discussed in the previous section. They help orient new teachers to the norms of the school environment, keeping them from being overwhelmed when those norms are problematic.

2. Support structures that allow time for working together and getting into each others' classrooms. It is as important for new teachers to observe their mentors as for their mentors to observe them. And time for processing the observations, articulating concerns and engaging in mutual problem solving must be a legitimate part of both teachers' work.

3. Assignments for beginning teachers that are not the most difficult nor the most complex. Often new teachers get teaching assignments that veteran teachers do not want: the most difficult children, for example. A good induction program recognizes the need for a new teacher to master teaching during that first year or two, a task that is difficult with even the least taxing assignment.

Many induction programs establish a set of indicators or expectations for new teachers and use some form of assessment to measure growth and mastery. Some incorporate test of research-based teaching skills, such as that used by the Kansas Internship Program (Burry et al., 1988) and the Connecticut State Department's Beginning Educators Support and Training Program. Others use a panel of experts (science teachers and science educators), to whom the beginning teacher presents a portfolio of his/her work, including videotapes, and talks through teaching activities (Collins, 1989).

Good induction programs are critical for good science teaching because they reinforce new teachers' inquiry-based teaching strategies, and help them choose appropriate curricula, set up sufficient routines, and feel comfortable with their teaching. They also reinforce the norm of continuous learning so that the teachers naturally seek more and diverse ways to grow and renew their teaching.

Since good science teaching is so scarce now, one might think about a new teacher having an overall mentor, with an exemplary teacher of science assisting in just the area of science. With creative assignments, a science mentor might assist more than one new teacher in the one content area.

Later Phase of Teacher Development:
Staff Development for Experienced Teachers

If all elementary school teachers had had the learning opportunities just described, this section would be shorter -- confined to discussing ways to help them renew and refresh their knowledge and skills throughout their teaching career. In fact, few current teachers have had such preparation, and so much of what was discussed earlier is equally relevant to staff development[1] for inservice teachers. Staff development opportunities must address the needs of teachers from those with little or no knowledge of science or science teaching, to those who are experts in both.

Good staff development programs for science teaching incorporate (1) knowledge about science, science learning, and science teaching; (2) strategies that help teachers develop and incorporate that knowledge into their teaching; and (3) structures that involve teachers in decisions about their learning and create an environment in which new knowledge is supported and renewed.

While the knowledge needed by teachers in service does not differ from that discussed for preservice, the change in teachers' employment situations (i.e., they are now full-time teachers) requires somewhat different structures and strategies to promote their learning.

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[1]Staff development as a concept is rapidly replacing the narrower inservice education, and because we prefer this broader connotation, we will use the term instead of inservice throughout this report.

Staff Development Strategies

Opportunities teachers have to renew their knowledge are typically either inservice workshops that are relatively short and one-shot, or university coursework that is highly theoretical. Both are apart from the context of their classroom and school. Some teachers remember the NSF-sponsored institutes of a decade or more ago, which were long, intense, and mixed theory and practice. But these too suffered from being apart from the teacher's home context. None of these approaches to staff development are optimal for learning and using new knowledge.

Loucks-Horsley and her associates (1987) report that staff development programs that result in meaningful changes in teachers' behavior have certain common characteristics. Among other things, they allow for intense study of and engagement with the new knowledge or skill over time, with time to practice and work through, with others, the problems of implementation. This combination of theory and application, time to reflect and practice, self study and cooperative learning, rarely is found in the more traditional inservice workshops, college courses, or even the early NSF institutes.

A model of the change process that has influenced many staff developers in their design of specific strategies is the Concerns-Based Adoption Model (CBAM) (Hall & Loucks, 1978). The model describes the process individuals experience as they are introduced to and implement new practices and programs. Seven Stages of Concern are identified that progress from individuals' concerns about what the program is and how it will affect them ("self"concerns), to how they will master all the time, material, and coordination demands ("task"concerns) to how the students are responding impact"concerns). Staff development strategies that address teachers' concerns as they emerge have been effective in helping teachers change their practice, in science as well as other areas (Loucks & Pratt, 1979).

Sparks and Loucks-Horsley (in press) identify five models of staff development that are quite different one from another, but that each have these necessary characteristics. The models are: training, observation and assessment, inquiry, curriculum and program development, and individually guided staff development. There is some overlap between the models and so one could in fact incorporate features of each in a comprehensive staff development program for science education. However, the models also offer alternative approaches that can be chosen among, depending on the individual teacher(s) and the context.

Training. The training model is most frequently equated with staff development and it is also the best studied; there are clear indications that its use can result in demonstrable changes in students (Joyce & Showers, 1988). The model includes (1) development of the theory and rationale behind the new behaviors to be learned; (2) demonstration or modeling; (3) practice in the training setting; and (4) guided practice in the field with feedback on performance.

> *In Jefferson County, Colorado, elementary teachers received training in the district's inquiry-based science curriculum through several phases. First, teachers were introduced to the new curriculum through short overview presentations by teachers who had piloted the curriculum. During these sessions they received their curriculum guides, learned about plans for inservice workshops, and had ample opportunities to ask questions. Second, in three full-day workshops scheduled through the year, teachers had opportunities to go through each teaching unit. Inservice leaders modeled teaching and classroom strategies, helping teachers to explore and practice the concepts and materials they would use with their students. Finally, experienced teachers on special assignment to the central office convened after school problem-solving sessions, were available to conduct classroom demonstrations, and in other ways supported the use of the new curriculum in the schools (Loucks & Pratt, 1979).*

Observation and Assessment. This model involves the careful observation of teaching, with particular attention to certain behaviors, and open discussion of the results. The model is labeled in various ways, primarily as forms of clinical supervision and coaching. A sequence of activities often includes: (1) agreeing on a focus for the observation, which may come from the teacher, the observer, or a framework established elsewhere; (2) the observation, with the observer recording behaviors as they occur or according to a predetermined schema; and (3) a conference during which the observation is discussed, strengths and weaknesses assessed, and goals for the future set.

As a form of supervision, this model has received much attention for its potential for formative rather then summative evaluation (Garmston, 1987; Glickman, 1981). As coaching, usually among peers, it encourages norms of collegiality and experimentation, associated with schools where students learn (Little, 1982).

To continue the previous illustration, the Jefferson County science department developed a guidebook for principals that describes the behaviors of teachers using their elementary science program. Each of twelve program components is spelled out as to what would be observed in classrooms where the program is being used as intended. Principals, who share responsibility for curriculum implementation in the district, use the guidebook to observe teachers and then to work with them, individually and collectively, to remove barriers to and provide support for good science teaching (Jefferson County School District, 1979; Loucks & Melle, 1982).

Inquiry. This model incorporates such practices as action research and reflective inquiry. Based on the work of Schon (1983) and others (Sparks & Simmons, 1989), teachers are encouraged to reflect on their own practice, gather data to better understand the phenomena of interest, and consider changes based on careful analysis.

At Devotion School in Brookline, Massachusetts, teachers working on a collaborative intern project with Wheelock College are able to take on roles other than direct teaching for 20% of their time. One teacher chose a Teacher/Researcher role. Early in the year he defined his problem: to examine the strategies that children used who were excellent writers of fiction and nonfiction. He learned research methods, conducted observations, interviews, and analyses, and wrote about his learnings in a paper he submitted for publication.

Curriculum and Program Development. Involvement of teachers in the development of curriculum and/or programs which they then use is another model for staff development. Teachers begin with a problem, e.g., the curriculum is outdated, needs review, is not being used; student achievement and/or enthusiasm for science is low. Teachers then gather information, materials and other resources, consider existing knowledge about effective science teaching and learning, and develop a response to the problem.

An illustration of such curriculum development comes from the Addison Northeast School District in Vermont. Following a district-wide process for identifying needs, the district curriculum coordinator put together a science committee that had a balance of perspectives and represented each school and grade level blocks. The only written curriculum was a 12-year old skills list. In the first year, committee members reviewed all the teacher resource materials they had and wrote a philosophy statement. Next they worked on the goals, scope and sequence.

Feeding into the new goals, scope and sequence were new science opportunities offered in the district, including a workshop on the geology of the area and mini-course in botany for elementary school teachers. Two teachers attended an institute in inquiry science offered in a nearby district, then conducted a workshop on physical science for elementary grades

The curriculum committee re-convened the next school year. By January, the K-12 guidelines were available for review. The document was not prescriptive, but rather provided a framework for each school in the district to work within.

Teams from each school prepared implementation plans, making decisions about which topics each teaching level would cover. Sample units were developed to provide models for teachers and material for curriculum evaluation. Meanwhile, staff development opportunities continued, including strategies for integrating science with other content areas.

The district is now focusing on a three year implementation plan that includes completion of individual schools' guides, continuation of district staff development programs, and support for implementation in schools. There will be release time for teachers to observe one another and stipends for teachers to work together during the summer on unit development.

Individually Guided Staff Development. This model is based on the assumption that individual teachers need different interventions to help them improve their practice. Here teachers, either as individuals or with others who share their interests or concerns, establish a goal, and seek input by way of coursework, workshops, library research, visits, and other forms of self study to reach the goal. Self determination and support by their principal, peers or others in the use of their new knowledge and/or skills makes this model different from more traditional staff development.

Pedie O'Brien is a second grade teacher at Bristol Elementary School in Bristol, Vermont. Her interest in inquiry science was piqued when she attended a summer institute in a nearby school district. She had taken courses at a natural science center and the nearby college and had attended any workshops in science she could find. But the practice she got in teaching science through an inquiry, hands-on approach during the summer institute pulled it all together for her. She decided to follow her natural inclinations, verified in her summer experience, by allowing the children to learn by asking questions and designing 'fair tests' for their ideas.

The next year was different for Pedie. She changed her own teaching and influenced the teaching of her peers. Her attitude spilled over into other curriculum areas. At the end of that year, with encouragement from the curriculum coordinator and her principal, she conducted workshops for the teachers in her district on the process skills *of science, the comparison of inquiry science to more traditional approaches, questioning techniques, and a content session on physical science. This helped her to both articulate and cement her beliefs and strategies.*

She also attended a regional NSF institute and came back with more ideas and a plan for implementing them. Together with her support person from the institute network, she will soon conduct a workshop in cooperative learning. As a member of the curriculum committee she is helping to find and fill the gaps in the present system. Teachers are now using her expertise, asking her to demonstrate teaching for them, or just to observe while they are teaching and provide feedback.

She attributes her success to her own motivation, the support she received from her principal and the fact that she "came from the inside" to work with her colleagues. "People here know me.., that I'm not a threat, but willing to work with them." Her principal put her in charge of implementing the science curriculum outlined in the district's guidelines. He listens to her ideas and encourages her to share them in both formal and informal sessions.

Staff Development Structures

These models work only to the extent that structures are in place to make them available to teachers and support their new learnings back in their classrooms (Loucks-Horsley et al., 1987). What good staff development structures have in common are (1) support for the practice and refinement of new behaviors in the classroom; (2) opportunities for teachers to talk and work together to reinforce, problem solve, and encourage change; and, in many ways, simply by their existence, (3) a clear message that the new behaviors are important and teachers are expected to use them. Several examples of structures for staff development for elementary science are:

Institutes. Similar in intention to NSF-sponsored institutes of the past, institutes can provide an intense, in-depth experience for teachers of elementary science. As discussed in the early stage of teacher development, the institute needs to provide teachers the opportunity to experience science the way scientists do, and thus the way their students should, rather than focusing on science teaching methods and materials. Learning to actually do science -- just as writing process workshops begin by having teachers learn to write -- prepares the teacher to create science learning experiences for children. It develops an appreciation for the combination of experimentation and exploration, with reading and talking to people who have scientific knowledge -- essentially "the work" of a scientist. Institutes model activities that are based on a constructivist and hands-on approach to scientific inquiry, with the organizing concepts of life, physical, earth, and space science as the content.

Institutes have traditionally been conducted apart from the school setting, with individual teachers as their target, and so have been limited in their ability to support classroom implementation. This problem is alleviated when institutes draw a critical mass of teachers from the same school; include the building administrator and/or science coordinator for at least a portion of the time; incorporate follow up activities closer to or actually in the schools, including teacher coaching and problem-solving sessions; and give attention to a wide range of implementation issues.

> *Simmons College, in Boston, Massachusetts, offered a two-week summer institute for teaching teams, with the goal of encouraging science teaching in elementary schools. The institute provided participants with sufficient information, hands-on experience, and opportunities to discuss the possibilities of inquiry science so that they could then evaluate their own programs and initiate change.*
>
> *Teams attending the institute included a principal or science coordinator, and a teacher. Each team developed a plan of action to promote science teaching in their school. In addition, their district committed itself to send another team to the following summer's institute. This was intended to build district support networks. Team members, who had to apply to Simmons to attend the summer institute, received an $850 stipend, four credits, travel expenses, all materials, and lodging.*
>
> *During the two-week session participants worked all day and evening, selecting from 40-50 workshops. Some of these workshops dealt with process science, misconceptions in science, intelligence and learning, career awareness, and evaluation for hands-on learning. Workshop processes modeled ones institute staff hoped participants would build into their own teaching. Special training sessions were held for administrators where they analyzed their leadership styles and examined how they might better promote and support science teaching in their schools.*
>
> *Institute participants reconvened the following fall to address additional issues. Each team was assigned a Simmons support person who met with them at their school twice a year.*

While this example institute is global in its objective of promoting good science teaching, others offer more in-depth study of a specific area. For example, during a summer institute at the University of California at Irvine, a one-week unit on matter gives teachers an overview of the discipline that encourages them to develop the depth necessary to introduce their students to the major ideas in the discipline, as well as classroom materials ready for immediate use. A combination of lecture, activities and homework assignments provide a depth to the topic that gives teachers solid science content to complement new teaching strategies. (Taagepera, personal communication, 15 April 1989).

Teachers Centers. These structures have the advantage of providing opportunities and support for teachers' use of new practices close to home. Teachers centers are sometimes in schools (Saxl, 1987) or within districts (Devaney, 1977), and are helpful in identifying needs felt by teachers and creating opportunities for those needs to be met. Because they have a staff, teachers centers can use a number of different staff development models, convening and supporting groups, identifying and assembling materials, bringing in expert consultants or trainers, coaching in classrooms -- generally providing the kind of ongoing opportunities and support needed to keep an effort from being one-shot.

One teacher center that works with elementary school science was established by the New York Coalition of Schools, whose mission is to address minority problems. As Coordinator of Staff Development for the center's science component, Maria Davis offers staff development at individual schools during the school day. Her aim is to help teachers feel more comfortable about teaching science, both with science content and inquiry teaching.

Once a month Davis offers workshops and follow-up support at each school on a variety of topics. She visits the teachers in their classrooms three times a month to observe science teaching or demonstrate a lesson. She provides continual feedback and coaching for the teachers.

The center also offers off-site workshops on a variety of topics after school and on Saturdays. Their work is bolstered by principals who are convinced of the importance of science and committed to good science teaching. As a result, more inquiry science is being taught and issues of equity are being addressed.

Other common structures for staff development include networks and partnerships. Linking teachers to sources of knowledge that can enhance their science teaching, these structures demonstrate useful alternatives to one-time inservice workshops by providing continuity and opportunities for ongoing support.

The knowledge and skills of teachers are of primary importance to the quality of elementary school science education. But the organizations within which they teach -- the schools, districts, and larger contexts -- play a major role in supporting the efforts of skillful teachers. The next chapter discusses the influence of organizational structures and supports.

CHAPTER III. ORGANIZATIONAL STRUCTURES AND SUPPORT

The quality of the science experienced by children in elementary schools is closely tied to the quality of their teachers and the kind of teaching they are able to deliver. In the previous section of this report we discussed the kinds of teacher development activities most likely to influence the knowledge and abilities of teachers to teach science. But able teachers need a context in which science is valued, in which good science teaching is not only expected, but supported at a variety of levels and along a number of dimensions. Some conditions, structures and policies enhance the possibilities for effective, satisfying teaching, while others frustrate them.

Currently, very little science is being taught in our country's elementary schools (Weiss, 1987). Several conditions appear to contribute to this:

- Few teachers know science and feel comfortable teaching it. This is also true of principals and other administrators who feel uncomfortable providing both leadership and support in the area.
- Emphasis in elementary schools is on language development and mathematics, to the neglect of science and other content areas.
- Few school districts have staff development programs that support their science curricula; rather, teachers voluntarily register for inservice workshops or summer institutes that may or may not relate to district curricula, and often these teachers are the ones most comfortable with science.
- Teachers feel unappreciated and out of control of decisions about how best to teach the children for whom they are responsible; schools are places where teachers are isolated, outcomes are uncertain and so uncelebrated, and the implementation of specific regulations appears to dominate both teacher and administrator activities.
- Teachers often have insufficient, inadequate, or inconvenient materials to teach science, particularly important if they are to use the hands-on activities known to promote science learning.
- Few school districts have systems that coordinate science goals, materials, staff development offerings, materials, program monitoring, and student testing.

Clearly, the current organizational contexts within which teachers teach science are insufficient to support teaching excellence. Yet these indicators alone suggest some changes that need to be made. While the research on how organizational context influences the quality of science curriculum and teaching is not particularly robust, there is a substantial amount of research and literature on educational quality, teacher professionalism, policy implementation, effective schools, and educational change that has direct relevance to the issue (Berman & McLaughlin, 1978; Darling-Hammond, 1986; Fullan, 1982; Murnane & Raizen, 1988; Purkey & Smith, 1983). This collective body of knowledge suggests that high quality education results in environments where: (1) expectations are clear, (2) support in both resources and opportunities for improving knowledge and skills is substantial, and (3) decision making prerogatives for competent, committed individuals are broad. Our discussion will consider several factors that promote these conditions. They include:

- clear purposes and outcomes
- adequate, appropriate resources, including time, staff, and materials
- a robust conception of staff development
- norms of experimentation, risk taking, collegiality, and collaboration
- involvement in decision making
- leadership and support

Clear Purposes and Outcomes

Research on effective schools and effective organizations indicates that being clear, united, and public about goals helps guide standards for excellence and behavior. When purposes are clear, the kind of curriculum that is to be taught, the instructional strategies to be used, and the nature of assessment can be specified much more readily.

Purposes and outcomes can be determined at a number of different levels. Several national efforts to do so in science education include the American Association for the

Advancement of Science's Project 2061 and our own Center's work on curriculum and instruction.

There are those who argue that purposes and outcomes should be specified at the state level, since it is there that the key policy levers exist, including teacher and school credentialing. Many states also exercise control over curriculum frameworks, textbook adoption, and student testing. Others argue that it is the district level where purposes and outcomes should be developed, since different student populations, resources, etc. must be taken into consideration. Still others believe that purposes should be stated at the school level, making the case that the school is the most critical unit for change.

We believe that these do not have to be exclusive positions. However, the argument that states should frame the general goals for science education is a compelling one, given their control of so many of the factors necessary for good science teaching, e.g., funding, teacher credentialing, student testing. When states take on this responsibility and do it well, educators from other levels help shape the purposes, and then are supported in all aspects of the education enterprise to implement them. California is an example of a state whose efforts to establish a science framework and an array of support mechanisms from textbook selection to assessment to staff development have the potential to promote quality science education statewide.

But some states have a tradition of local control or lack the resources needed to engage in a goal-setting process that draws input from all levels of education, plus the scientific and general community. In these cases, the setting of purposes and outcomes should fall to the district, where expertise and resources are likely to be concentrated.

We are least inclined to support the idea that schools are the best unit for establishing the goals and outcomes of science education. While some school-based improvement efforts have had substantial effect on student reading achievement, there is little evidence that the same outcomes accrue for science. Because science is a low priority for many elementary school educators who do not feel confident about their knowledge of science curriculum and instruction, there is some danger that the quality of the program may suffer. We note later that schools (and individual teachers) should have other decision-making prerogatives. In most cases, however, the setting of general purposes and outcomes for science teaching should be done at another level, with input from teachers into the decisions.

The development of clear purposes and outcomes allows for:

- a sharpened focus for program development efforts, enabling the players at the various levels to come together with a common agenda and screen out many of the distractors common to their task
- the design of success indicators that enable people to know what they must do to succeed, when they have been successful and what areas need special attention
- more informed decision making about the programs, textbooks or other materials that will be the primary vehicles for instruction.

Resources and Their Allocation

As schools and districts organize their resources, they establish processes for conducting the work of teaching and learning. These have considerable influence over what is possible and likely in classrooms. Among those most relevant to elementary science teaching are the nature and quantity of available resources, staffing and time.

Research has pointed out that the relationship between the level of resources (e.g., per pupil expenditure) and educational quality is less important than how the available resources are used (Murnane & Raizen, 1988). It remains a fact, however, that teachers who do not have materials and facilities available to teach activity-based science are less apt to do so than those who do. The availability of knowledgeable staff, facilities, equipment, curriculum materials -- these "set the parameters within which schools operate . . . [by defining] the outer limits of what is possible" (Darling-Hammond, 1986:49).

Staffing

Staffing patterns are important to the quality of science teaching, since the opportunity to learn science is optimized for elementary school children by the availability of teachers who are knowledgeable, enthusiastic, and committed to teaching science. But should every elementary school teacher be required to teach science? The answer to this question is complicated by the fact that the current emphasis in teacher development is on the basic skills of reading, writing, and arithmetic. In a great many situations, teachers are chosen and assigned by their abilities to teach language arts, which is a higher priority in today's schools, especially those serving urban or limited-English speaking populations.

Options such as the use of science specialists are seen by many as preferable to children receiving no science instruction, or instruction that is poor. Such specialists can play different roles. They can teach all the science lessons for the school or for certain grade levels. They can be members of a team where they are responsible for science and another content area (e.g., math), planning together with other team members the overall program for their students. They can do all the planning and preparing for science lessons, which they and the other teachers then teach. Or they can have limited teaching responsibilities of their own, working instead with other teachers in their classrooms to demonstrate or assist, and outside of class where they help teachers develop new knowledge, skills, materials, and programs for science teaching.

There are, of course, advantages and disadvantages to each of these roles. The first may eliminate possible integration of science with other content; children can get the idea that science is a separate, special area that requires special talent to teach (and do). It also keeps one teacher from knowing "the whole child" in every area of schooling -- important in primary grades. The first three roles allow non-science teachers to forget about science as something they know and share the wonder of with children. Even the third -- where all teachers teach units developed by the specialist -- runs the risk of having a teacher go through the motions of a science lesson without really engaging with the children's learning. And the last role is expensive: it requires a full, or nearly full-time equivalent teacher.

Decisions about the use of science specialists in elementary school are situation-specific. We prefer having specialists in the last role described, although they may work with teachers in several schools, rather than just one. Such a system is used in the Mesa, Arizona, School District, where four full-time "resource teachers" work with the district's 42 elementary schools. These teachers have responsibilities for both curriculum revision and training. In the latter role they work closely with new teachers, conduct long-term training programs in cooperative learning, and offer a variety of other staff development opportunities and support to teachers.

When resources to support this role are not available, schools might decide to use specialists in one of the first two roles, especially in grades 4-6, where science content becomes more important. In the primary grades, teachers with limited science knowledge, but a good staff development program and a set of inquiry-based science materials, can handle science without a specialist, particularly if they are concerned about knowing the child across content areas. We would prefer the use of specialists even at this level, however, where the alternative is a teacher who is neither prepared nor inclined to do good "hands-on, minds-on" teaching.

School staffing patterns are a primary dimension in the current movement toward school restructuring (Harvey & Crandall, 1988). While restructuring schools around content specialties appears to be most relevant to our discussion of science teaching, other differentiation of staffing may enter the picture. For example, a school restructured to provide meaningful practice teaching opportunities for prospective teachers would have interns and/or student teachers, raising the adult-student ratio and lending itself to more investigative, individually paced and self-directed science learning (Smylie et al., 1988). In the Carnegie Report's (1986) Year 2000 scenario, a restructured school has additional staff who contribute to teaching science, including a lab technician and a scientist on leave from a local firm.

In the previous chapter we used the intern project at the Devotion School in Brookline, Massachusetts as an example of teachers taking on different roles in a restructured setting. When teachers are part-time researchers, teacher trainers, and curriculum developers, as in that example, they begin to break down the simple (and simplistic) role differentiation common in our schools, where teachers all have the same job. Identifying teachers with special talents to act as mentors, advisors, resource teachers, and trainers can have important implications for the quality and quantity of science teaching in schools. More creative staffing patterns will most probably be common in schools of the future.

Time

The amount of time allocated to subject areas is one indication of its importance to the school community and contributes in important ways to student learning. Studies have repeatedly shown that the amount of time spent on a topic influences student learning (Raizen & Jones, 1985), yet the average amount of time elementary teachers allocate for science is minimal (Weiss, 1987). The expectations created at the school and district level, the scheduling of activities within the school, and the degree of comfort felt by the teacher about teaching science -- all influence the amount of time spent on science in elementary classrooms.

The NSTA has recommended the minimal amount of time that should be spent per week in science instruction as two and a half hours in the primary grades and four hours in the upper grades. Our Center's Curriculum and Instruction report (Bybee et al., 1989) suggests twice that amount for science and technology education. Such time allocations indicate a commitment to a consistent, regular inclusion of science in the school program. Whether set at the district or school level, they require attention by teachers and administrators.

The focus on the amount of time given to science teaching diminishes in importance when curricula are integrated (Jacobs, in preparation). As in Ms. Lopez's second grade, a science unit can easily become the focus for an entire day's activity, including reading, writing, speaking, mathematics, and social studies. What is important to guard against is defining the integration of science as treating it through reading and writing only. The kind of experiential language development currently called for by proponents of whole language instruction suggests a more appropriate alternative for integration with science. For example, teachers can use science investigations to stimulate student debate, discussions, and creating writing. The kind of assessment called for by a constructivist approach to teaching generalizes across content areas as well.

Materials

In a curriculum area such as science, materials play a key role. The absence of good materials often precludes activity-based teaching. As our Center's Curriculum and Instruction report indicates, textbooks are the predominant material for science teaching in today's schools. While he *concept* of text materials that support hands-on activities is not bad, current textbooks have an overabundance of disconnected factual information that does not necessarily lead to conceptual development.

Yet there are a variety of excellent sources from which science materials can be drawn. These include existing curricula such as SCIS (now available as SCIIS) and ESS whose activities are captured, along with others developed with NSF funds, on the CD-ROM Science Helper mentioned earlier; programs made available through the National Diffusion Network such as Life Lab and the Hands-On Elementary Science program; and the recently funded NSF elementary science development projects. (See page 35 of this report for more detail.)

The cost of good science materials is not to be minimized. It has been estimated that a budget equal the cost of a textbook program is needed for the materials and supplies to support a hands-on program.

Several important factors must be considered when selecting materials (Loucks & Zacchei, 1983). The first is coherence with the existing science framework. It is easy to assemble an assortment of motivating, exciting science activities for children. It is even possible that they may learn something from each. But a real science curriculum is not piecemeal. Rather, it supports a framework of agreed-upon goals and objectives, or a set of organizing concepts such as those proposed in our Center's Curriculum and Instruction report. Every science activity adds one more building block to the achievement of those goals or to the learning of those concepts. This is one of the problems with the limited amount of computer software available for science today. Caught up in the excitement of new technology for themselves as well as their pupils, teachers use whatever is available, resulting in a discontinuity of curriculum. Good materials selection plays a key role in promoting a coherent, comprehensive science program.

Another important factor concerns quality control. It is critical that the materials used to teach science have indeed been proven to promote the desired science outcomes. As noted earlier, materials need to be aligned with the stated goals and desired outcomes, as well as with assessment procedures. This requires careful testing if materials are developed locally, or inspection of evaluation processes and results if materials were developed elsewhere. It argues against developing a school or districtwide curriculum by pooling teachers' favorite activities without testing it as a coherent package against the specific outcomes science instruction is supposed to promote. Ensuring the effectiveness of science materials with children and teaching situations similar to one's own is important to effective science education.

But the availability of good materials by no means ensures that they will be used. It is no surprise that activities that are difficult for teachers to use in the classroom -- ones that require an inordinate amount of time to prepare for, set up, clean up, and manage with a full class roster -- are not likely to be used regularly. Materials more likely to be used are ones that are self-contained, clear in their procedures and their requirements, and able to be managed under normal classroom conditions (Loucks & Zacchei, 1983).

Good systems for maintaining science supplies and equipment and classroom facilities that allow for mess and movement can facilitate the use of materials called for by exploration and hands-on activity. Such a system acquires, organizes, distributes, and replenishes the materials needed by teachers. This can be done in an individual school by a science specialist with a large storeroom and released time. But, exemplary science programs typically have a district-level system that delivers to teachers everything they need when they need it. This calls for a person with responsibility for the system, teacher requisitioning procedures, materials identified through suppliers or locally, storage space, and transportation.

In Anchorage, Alaska, more than 1,000 elementary teachers in 55 schools get the supplies they need to teach science through a district-wide system. Each year, teachers teach at least four science kits to their students. Early in the school year they complete a form *which alerts the Science Center to their schedule and their needs. The Center staff orders and stores all the materials needed to teach the kits, assembles class-size sets of materials, maintains a truck delivery route so teachers receive materials when they need them, and inventories, cleans and replenishes all materials when they are returned.*

The National Science Resources Center at The Smithsonian disseminates information and provides assistance to science educators interested in developing materials support systems for elementary schools.

Staff development programs that guide teachers through the hands-on activities and provide them with tips on how to manage materials and children can prevent premature decisions by teachers that activities cannot be done under normal classroom conditions. Help with using materials effectively and efficiently in the classroom can be as important as having the materials readily available.

Additional Resources for Science

Good science teaching cannot occur without funding. While there are ways of reallocating resources or cutting corners (e.g., having vocational education students make some of the equipment), there still are real costs associated with developing and supporting teachers to teach "hands-on, minds-on" science.

More ways are needed to get multiple mileage from budget dollars and additional monies from sources other than local allocations. Business and industry sources have been used to equip science classrooms, to infuse activities with scientific expertise, and to supplement district staff development. Local museums, botanical gardens, and/or parks have exhibits, staff, and facilities that can enrich science learning.

Rather than investing in a new science program all at one time, one or two units can be developed each year, using discretionary money to purchase necessary materials and equipment (National Science Resources Center, 1989).

There are also federal funding sources that support science teaching. For example, school districts have access to both Chapter 2 and Title II funds. Chapter 2 funds have been used in a variety of ways, often, at least in the past, for the purchase of microcomputers and other materials. Districts, however, have discretion over how the funds are spent. Title II, also known as the Federal Math/Science Retraining Act or, in its most recent reauthorization, the Eisenhower Act, allocates funds to districts on a per pupil basis. These funds are largely for the purpose of staff development for both science and mathematics. Other Title II monies go to institutes of higher education to develop programs for math and science teacher training.

Local science educators may also benefit from the reauthorization of Chapter 1 funds for children from low-income homes. The 1988 reauthorization reiterated the definition of "basic skills", previously interpreted to include only language and mathematics, to include science and history. There are several implications of science being part of the core program for Chapter 1 students. First, it argues for ensuring that they have strong science programs, that they not be pulled out of science classes for remediation in other areas. Second, Chapter 1 resource teachers and aides need to be included in science staff development, especially because they serve populations that are often the most "science-phobic". The potential for becoming part of the training and support system for Chapter 1 students provides the creative science educator with opportunities to serve a larger number of teachers and reach more students who are underrepresented in science classes later in their schooling.

A Robust Conception of Staff Development

A major part of the previous chapter discussed the importance and specifics of effective staff development for the teaching of elementary school science. Here we put it into context of the organizational structures and support needed to help individuals change their level of knowledge and skill for science teaching.

Odden and Marsh (1988:598), whose concern is with implementing large-scale reforms, note that

> The emerging mode of staff development addresses broader and more complex issues, is provided over longer time periods with considerable ongoing assistance, is linked to

strategic directions of the district and the school, and is targeted to specific issues rather than across an array of disconnected areas.

This appears to be what is needed for the kinds of changes required by our new vision of science teaching and learning. Rather than numbers of disconnected staff development offerings, there need to be coherent plans that support curriculum, instructional, and assessment decisions made at the state, district or school level. For example, a district science program is accompanied by a series of workshops for teachers, with in-classroom coaching as teachers try out the new materials. This is not to say that teachers should be discouraged from following an interest in some aspect of science and pursuing it in some of the ways described in the previous chapter. It does, however, mean that a significant amount of the resources for staff development should be allocated to implementation and support of curriculum.

Critical mass is important in this view of staff development. Teams of teachers or teams of teachers and administrators attend training sessions, rather than individual teachers on their own initiative. The intent is to simultaneously build knowledge about science learning and teaching, while forging strong working relationships and support structures. The aim of staff development is to build individual and organizational capacity at the same time.

Staff development is not only appropriate for teachers, but for administrators and district science leadership as well. Our view of science teaching requires that efforts to change teaching approaches are managed well, supported along a number of dimensions. To do so, leadership training in the new support roles is necessary, such as that currently being offered by the National Science Resources Center and the National Science Supervisors Association. Leadership training is also appropriate within the district, particularly for principals, who need to know about what good science teaching looks like, ways they can observe it, and how to work with teachers in their efforts to improve. Principals and science leaders especially need to know the importance of encouraging teachers to persist in trying new approaches, to remain faithful to the design of the program until they have mastered it, rather than giving it up or changing it in a major way that keeps them from achieving the outcomes associated with the program. Balancing assistance with "pressure" is a skill that science leaders must develop (Crandall, 1983).

One of the most important aspects of this robust conception of staff development is that it is both in-depth and long-term. For many whose knowledge of science is thin at best, intensive institutes may be called for, where participants are immersed in the work of science, learning processes and content together through investigations of the natural world. Such an approach is common for teachers of writing who often attend multi-week institutes where they become writers first, before analyzing the writing process and its implications for their own teaching.

But such an in-depth experience requires substantial follow-up once participants re-enter their real world; this is a consideration few NSF-funded institutes of the 1960's and 70's understood, and why many of their enthusiastic participants never implemented the new programs and processes into their teaching. Even the best staff developers rarely plan for the amount of continuous support needed by teachers to significantly change their teaching. As recommended by Crandall and his associates (1982), plans for projects promoting real change in classrooms should allocate half the budget for initiation and initial training, and the other half for ongoing training and support. And such support should last at least throughout the two to three year implementation period.

One strategy used to sustain a long-term staff development effort for curriculum implementation is for teachers to take on training and support roles (Loucks-Horsley et al., 1987; Loucks & Pratt, 1979). A training-of-trainers strategy includes the selection of competent, enthusiastic teachers; preparing them to teach the curriculum and then having them do so; training them in the principles of adult learning and the change process, and in the skills of training, consultation, and evaluation, and supporting their growth as trainers by promoting collegiality and experimentation. These teachers can then function in a variety of roles: as workshop leaders, follow-up consultants across a number of schools; resource teachers within their schools; special science mentors for beginning teachers (mentioned in an earlier chapter); and science specialists for their teaching teams. Through this strategy, capacity is built at the individual, school, district and often the regional and/or state level.

Organizational Norms That Support Learning

Science is a way of knowing about the natural world. In the elementary grades good science teaching encourages students to wonder, to explore, to discover, and to develop conceptions of how the world works. Classrooms where such teaching occurs value questions, experimentation, risk taking, and collaborative problem solving. For teachers to foster these behaviors they too need to exist in an environment where these behaviors are valued. The same conditions that make classrooms good places to learn science, make schools good places for teachers to continue to grow professionally and feel good about their work.

Schools where teachers feel comfortable proposing and trying out new instructional strategies and materials, and where they routinely share with each other at several levels -- from talking about teaching to co-developing units of instruction -- are more effective in increasing teacher as well as student learning. Breaking down the traditional barriers between teachers that foster isolation and autonomy results in greater experimentation in classrooms, shared responsibility for student learning, and greater teacher commitment (Lieberman & Miller, 1988; Rosenholtz, 1989).

We noted in our discussion about staffing patterns that the need to teach science well is a motivating force for teachers to work together. Sharing children, where each teacher can teach what excites him or her and still consider the total education of each child, puts what is quite a serious responsibility in the hands of several rather than just one teacher. And the clear benefits of sharing the organization of materials, equipment and other resources for hands-on activities also accrue from this kind of a teaching environment.

When teachers work with those in other roles, in addition to working with each other, similar norms are developed and reinforced. They are able to maintain the all-important focus on the learner. Cross-role teams have been found repeatedly to be important vehicles for planning and supporting curriculum development and implementation efforts (Odden & Marsh, 1988). Such structures foster understanding of the perspectives and realities of people in other roles, forging solutions that will work for all, and building trust to allow for experiments and risk taking in designing creative approaches to meet new demands as well as address persistent ones.

Involvement in Decision Making

The question of how teachers should be involved in decisions about science teaching is quite complex. The research on teacher participation in decision making is relatively new, and there is none to date that focuses on elementary school science.

What is most problematic is trying to generalize from the literature on teacher professionalism, which asserts a clear connection between teachers' commitment and effort, and the extent to which they are involved in instructional decisions (Lightfoot, 1983). Darling-Hammond (1986) notes that, when teachers are involved in decisions about such matters as instructional materials and methods, structures and programs, and directions for improvement and staff development, absenteeism and turnover decrease. There is greater consensus about school priorities and practices, coupling more tightly the goals, content, activities, and assessment, and thus, positively altering what goes on in classrooms. Combining school wide influence with a degree of autonomy over classroom curriculum and instruction "helps shift teaching away from technical work and towards professional practice" (Darling-Hammond, 1986:62).

The degree to which these statements apply to elementary school science is unclear. As noted earlier, the training and preferences of elementary teachers favor language and perhaps mathematics, but rarely science. If given options, will they choose to give science the emphasis it deserves? Will they work towards having an exemplary science program in their school such as we have described? Indeed, Al Shanker, President of the American Federation of Teachers, has observed that teachers involved in school-based management projects where they are the primary decision makers often do not look to current research or exemplary practice to inform their decisions. His concern is that their uninformed decisions will serve to perpetuate the status quo rather than contribute to meaningful changes in their schools (Shanker, 1988).

Research on the implementation of new practices in schools, which has included examination of science programs, indicates that teachers who are not involved in initial implementation decisions often develop high levels of commitment anyway if the practices.work well for their students. Huberman and Miles (1984) reported that implementation was more successful in efforts where mandates removed teachers' prerogatives to select their own approaches. The combination of a program carefully selected for its effectiveness with a similar learner population, strong credible training and follow-up support, and a mandate that teachers would use the practice in their classrooms, ultimately resulted in successful implementation, impact on students, and teacher satisfaction. The key to understanding their scenario is that, while teachers had little or no commitment to the program to begin with, they had good training that convinced them and enabled them to use it, and they soon observed its impact on their students. Thus their commitment grew as their behaviors changed in ways that obviously benefited their students. As Fulian (1982) posits, doing is believing.

This discussion underlines the important learning that no single factor alone influences the process of educational improvement. McLaughlin (1987) notes that success depends on two broad factors: capacity and will. Capacity building, while difficult, can be addressed directly through such strategies as staff and leadership development. Will, on the other hand, is more illusive. It is influenced by such factors as environmental stability and competing centers of authority, priorities, and demands. One learning from the research of Miles and Huberman (1984) and others (Guskey, 1986, Fulian, 1982), is that will can also be influenced by action. Teachers can develop deep, tenacious commitment to a program they have tried that works well with their children -- even if those teachers implemented that program reluctantly.

What does this say about involvement in decision making about science? Earlier in the chapter we discussed the importance of having clear purposes and outcomes that are based on what is known about good science teaching and learning. As McLaughlin (1987) indicates, such clear goals and authority are important initially to focus attention and create clear expectations and priorities. While this broad pressure should not let up. implementers then need to move in to address issues of program development and provide support required to ensure quality of implementation. Thus decisions about curriculum, instructional strategies, and materials must involve those who will be called upon to support and implement them. The kinds of cross-level teams described earlier are vehicles through which such decisions can be made, at least at the district level.

Teacher involvement on these teams is critical to ensure that the science program, and its many dimensions, will be "classroom friendly" and adequately supported. But where is teacher decision making most important? We believe that they should have a major role in implementation decisions: how and when to introduce new curricula into their classrooms and school; how staff development should be structured and delivered; who should be teaching what and how; how to support each other in their teaching; and what special adaptations are needed for their particular students.

The determination of what kinds of involvement teachers ought to have needs to be made for each situation. Here is where the role of leadership becomes so critically important.

Leadership and Support

Leadership may be the element that binds and makes meaningful the array of factors discussed within the organizational context, especially the last. One of the most important tasks of leadership is to involve people from all levels in decisions. The work of Kanter (1983) and others who study effective organizations, including schools, indicates that good leaders provide clear structures within which decisions by others can then be made.

In education, leadership and the structures such leaders develop come at several levels. State structures for science, for example, can be in the form of curriculum frameworks such as those in California, and state assessments such as those under development in Connecticut. At the district level frameworks, curriculum guides, and assessment strategies can form clear structures within which teachers and others can work. When a variety of individuals in leadership positions participate in the decisions related to these structures, the structures are more likely to be viewed as helpful and supportive than as confining and dictating. Further, when the structures clearly leave room for a range of decisions within them, individual teachers can have opportunities to work in an "autonomous and creative way" (Kanter, 1983:248).

Leadership does not have to be restricted to those who hold formal positions of authority in an organization (Cox et al., 1987). While the building principal has been cited by many as critical to the effectiveness of a school (Fullan, 1982), others may in fact play equally if not more important roles in overseeing and/or supporting school programs, particularly specific curricula. It may, in fact, be more useful to think in terms of the functions leadership must play, rather than what a particular leader must do. For example, examination of science programs recognized in NSTA's Focus on Excellence indicated that, in each case, someone took responsibility for designing the program (Yager, 1984). In some cases, this was a central office administrator, in other cases a master science teacher. In different situations, different configurations of leaders from the school and district, and even from outside the district, are needed to help teachers initiate, implement, and sustain curricular and instructional changes.

There is also evidence that people in certain formal roles may be the best for particular jobs. For example, in their study of a wide variety of school improvement efforts, Crandall and his associates (1982) found that a central office curriculum leader often had the most influence over what teachers did in their classrooms, while principals aided the effort by maintaining stability in the school and external trainers or consultants helped plan for the kinds of long-term organizational support teachers would need to maintain the programs. In some cases teachers played key leadership roles. The learning that a variety of leaders is required to make a lasting improvement in schools suggests the need for the kind of cross-role leadership teams mentioned earlier.

Research on implementation confirms leadership's role in providing clear direction and creating clear expectations about "the way we do things around here." Miles (1983) points out the importance of school and district administrators maintaining pressure on teachers to give new practices a fair trial, and to do so in a way that is faithful to the original form of the practice. Too much latitude resulted in practices so watered down or drastically changed that the outcomes they were designed to achieve were lost.

Elementary teachers, for example, who are inclined to give up the messy and hard-to-manage live creatures in their curriculum can easily lose the element that makes life science most meaningful to their children.

Such pressure has impact only when combined with the promise to provide all the assistance and support necessary to make a program work. Thus the other critically important role leaders play is to ensure that such support is forthcoming. The most obvious kind of support involves opportunities for skill acquisition and development, addressed earlier in our discussion of staff development.

There are many other ways to demonstrate support, however. Leaders at the school and district level have the authority to create and retire priorities in schools, and the support they give new programs hinges on how they act out that authority. Items of high priority are allocated time and other resources -- those of low priority are not. This is particularly important for science teaching, which has typically been a low priority in elementary schools.

Support for science teaching, which can be given at either district or building level or both, may also include:

- providing released time for teachers to attend training and to prepare for science teaching
- protecting teachers from other demands, including additional innovations, priorities, visitors, etc., especially while trying out new activities and materials
- ensuring that the supplies and equipment teachers need are readily available and are replenished continuously, and that the help teachers need is forthcoming
- publicly announcing -- and continuing to do so -- that science is a high priority in the school and that children need adequate opportunities to learn science
- providing encouragement to teachers while they experience the discomfort of trying new activities, while being clear about the expectation for continued use
- using a variety of incentives and rewards for teachers who teach science effectively, including recognition, new roles, opportunities to attend conferences, conduct training, etc.

- rearranging schedules such that the time and location of science teaching works best for teachers and any collaborative planning or development is facilitated (Loucks-Horsley & Hergert, 1985).

Research can tell us a great deal about the ingredients required to successfully change and maintain the kinds of knowledge, skills and classroom behaviors associated with good science teaching. Yet the skillful and wise combination of these ingredients that match a particular situation's strengths and liabilities is the challenge of leadership. As we note in the final chapter, much more needs to be learned about how this happens.

CHAPTER IV. RECOMMENDATIONS

Our synthesis of research and practice related to the preparation, induction, ongoing development, and organizational support of elementary school teachers of science leads us to a single conclusion: While there is a substantial amount of knowledge about what needs to be done, as well as about how to do it, what is lacking is a coherent and comprehensive structure that provides support for elementary science education from all parts of the system. The research in most of these areas has consistently and over time provided many important learnings. In many instances, schools, school districts, states, universities, professional associations, and other organizations are applying individual segments of these learnings in some very fruitful ways. The challenge for the future, however, is to bring all of the discrete pieces together for the first time.

There is a wide range of simultaneous changes that must be made for our vision of "hands-on, minds-on" science teaching to become a reality. For example, we need newly designed college science courses for prospective teachers so that they can understand the nature of science and science learning sufficiently to help children develop their own understandings of the natural world. But well prepared teachers cannot teach science as it should be taught if their schools have other priorities, insufficient materials and equipment, and norms that discourage experimentation. Similarly, prospective teachers need models of good science teaching, yet those models will be rare if better staff development is not forthcoming. There is no one place to begin; we must work simultaneously on all parts of the system, with full attention to collaboration and articulation across levels.

Our recommendations are presented in the context of two goals that encompass the full range of levels and issues. Our learnings lead us to believe that there is a major need for an infrastructure which will, like the framing of a new building, give shape, boundaries and support to the rooms within. Therefore, we begin the discussion of our recommendations by asking what structures and supports are needed to promote good science teaching. Once we have suggested such a framework, we focus on specific parts of the system and suggest some ways their functions and operations need to change.

Our improvement goals guide our recommendations in two areas: organizational structures and support, and teacher training and development. Within each area we make a range of recommendations for development and demonstration, staff development, dissemination, and research.

Goal #1: **We must develop structures and support at local and state levels that ensure that teachers who know how to teach good science can teach it in a professional and supported manner.**

We envision an educational system in which teachers are sufficiently knowledgeable, skilled, and positively inclined to teach science well. They would not have the kinds of structures and supports needed to do so, however, if schools, districts, and states continue to be as they are today. In this report we suggest that schools, districts and states need to provide their teachers with clear expectations, sufficient materials and staff development, opportunities for collaboration and shared decision making, strong leadership, and ongoing support for their development as teachers of science.

Goal #2: **We must provide means for all teachers to develop the understandings, positive attitudes, and abilities to teach good science and to continue to grow throughout their careers.**

In this report and in our Center's report on curriculum and instruction, we portray good science teaching as selecting content that incorporates nine organizing concepts and using a four-stage sequence for instruction, based on a constructivist approach to learning. This kind of science teaching will meet the needs of all children, and is particularly important for those at risk of school failure. Yet this kind of teaching requires preparation that is quite different than that currently experienced by elementary teachers.

We have suggested taking a constructivist approach to not only the teaching of children but also to the way both prospective and inservice teachers are helped to learn what they need to know about science, science learning, and science teaching. This requires that in coursework and staff development offerings, learners are helped to articulate the meanings they hold of important concepts, and are provided with sufficient experience and information to enhance and elaborate those meanings in ways conducive to good science teaching.

To develop teacher knowledge and skills in science teaching, teacher education needs to be viewed as a continuum, beginning with a sound liberal arts education that includes science coursework and continuing throughout the career of the teacher. Responsibility for teacher education should gradually shift from institutions of higher education to schools and school districts. Staff development opportunities for inservice teachers must be long-term and coherent with the goals for science learning.

Our first recommendations revolve around the imperative of linking and coordinating the efforts of many disparate individuals and groups. liberal arts and sciences faculties; teacher education faculties; professional organizations; state certification staff; state education agency testing staff; state education agency science staff; school and district administrators; district science coordinators; district and school staff developers. Because so many of the moving parts exist at or are influenced by the state level, where an unprecedented amount of activity has occurred over the past several years, we believe that the state must play a key role in articulation of science teaching. At the same time, we recognize that the structures and supports for science often operate simultaneously at state and district levels. We have no preference about how much control the state should have versus the district since our synthesis of research and practice has allowed for no such conclusions. We do, however, believe that certain structures and supports need to be present at one or both levels, and certain kinds of input are needed for the structures and support systems to be valid, practical and effective.

1. <u>Recommendation for State and/or District Structures and Support That Promote Good Science Teaching</u>:

> We recommend that states and/or districts develop comprehensive structures and support systems that have, at a minimum, the following elements: 1) shared purposes and goals of elementary science; 2) links to teacher certification and assessment; 3) student assessment; 4) cross-role teams for planning, decision making and coordination; and 5) comprehensive staff development (including leadership development). In addition, districts should have systems for 6) curriculum development and 7) material support

Structures that incorporate these elements to support good science teaching are indeed rare. At a minimum, the goals of elementary science need to be specified at the state level, although there is a compelling argument to be made for a state framework that also specifies a core of science knowledge and skills. If a state framework does not exist, a district framework is called for. Such frameworks provide guidance for the selection of programs, textbooks and other materials with which to teach science, and for the specific instructional strategies teachers need in their repertoire to promote good science learning.

Once it is clear what children should learn from science teaching, then the knowledge and abilities to teach to those goals need to be incorporated into the licensing and ongoing evaluation of teachers. This would influence teacher training institutions to be certain that their graduates have had opportunities to develop those knowledge and skills. It should also influence the design of district teacher evaluation systems, since the expertise required of an evaluator is likely to exceed that of the generalist administrators who typically conduct teacher evaluations. In addition, it should influence the design of student assessment, including tests to evaluate the program overall, and procedures with which teachers monitor student learning.

At each level, cross-role teams should represent those who share responsibility for science teaching and learning. At each successive level getting closer to the classroom, the decisions made by the teams become more specific and subject to individual contexts. Policies are decided at state and district levels; implementation decisions are made at district and school levels; and decisions about day-to-day operations are made at school and classroom levels. Each team is responsible for a plan that coordinates and links elements at their level. For example, a district team might coordinate materials selection, staff development, and student assessment. A building team might coordinate teacher assignments, material provision and storage, and collegial coaching. Further, teams should be responsible for monitoring the implementation and impact of science teaching at their levels.

Staff development that relates directly to the knowledge and skills specified in the state or district framework must be available. Carefully planned, ongoing training in science content and pedagogical skills should be complemented by the development of expert lead or resource teachers who are available to train, coach, and support others; mentors who model good science teaching to work with beginning teachers; opportunities to engage in colleague coaching, study groups, and action research, all directed at improved science teaching.

Finally, leaders at all levels are required who know science learning and teaching and, in particular, can articulate and promote the state and/or district science framework. Such leaders must also be skilled in areas such as group process, training and technical assistance, supervision, curriculum development, evaluation, and planning. Special attention should be paid to state and district supervisors of science, as well as those who take responsibility for science at the local level in the absence of a science supervisor.

At the district level, in addition, structures and systems for curriculum development and materials support are called for. These involve the identification and selection or development of materials for teacher use that are aligned with the selected goals, and procedures for acquiring, organizing, and supplying teachers with the materials required for hands-on science activities.

These components are all needed for long-term comprehensive change in state and district science education. But what of districts (or even, perhaps, schools) who want to begin tomorrow to make a difference in science learning? Where might they begin to get the most rapid change to occur?

A "quick start-up" strategy might include:

1. A <u>shared leadership team</u> of selected teachers and administrators who assess the current state of science teaching and resources, select a science program, oversee training and support for teachers, monitor progress, and communicate regularly both inside the system and with the community.

2. An <u>existing, exemplary science program</u> selected from among those recognized by NSTA, the NDN, or the NSRC (see page 35 for detail), and adapted for use with the particular student population and resource base.

3. A set of <u>pilot teachers</u> who spend a year mastering the program with help from its developer and being prepared as a <u>training and support cadre</u> for full implementation.

4. A <u>two-year training sequence</u> for all, with the first year having up to three days of released-time workshops when teachers learn how to teach the units, and the second year of up to three days to improve teachers' understanding and skills in inquiry teaching, cooperative learning, and approaches to assessment.

5. A <u>support structure</u> which provides teachers with all the materials they need for teaching, and makes individual help and coaching available to them on a regular basis.

6. A <u>program of awareness and training</u> for people other than teachers, such as principals, library and media specialists, and resource teachers to orient them to the new program, how it relates to other programs and the support roles they need to play.

We recognize that neither this "quick start" approach, nor the more long-term, comprehensive one outlined earlier, can be successful without more good models of how the various components can be developed and combined, given the resources typically available to science educators. This is particularly true at the district level. The next recommendation addresses this issue.

2. Recommendation for Demonstration and Dissemination of Exemplary District Programs:

We recommend that funding and technical assistance be available for districts whose science programs support the kind of science teaching we promote, have demonstrated impact on student learning, and who are committed to becoming a demonstration site and disseminating their programs to other interested districts.

It is far less expensive for districts desiring a new science program to adopt or adapt one that already exists, rather than developing their own (Crandall & Loucks, 1983). Several district elementary science programs have been identified and designated as exemplary by the NSTA's Focus on Excellence program, the National Diffusion Network, and the National Science Resources Center. Yet there are not nearly enough to model the attributes of a new "hands-on, minds-on" approach; nor are they geographically accessible to enough school districts; nor have all been examined carefully enough to know what makes them exemplary; nor do they range sufficiently in the kinds of children they serve or the amount of resources they have. In addition, the exemplary programs that currently exist have not had the support or assistance needed to enable them to conduct the kind of dissemination and implementation support activities that would be useful to other districts.

We recommend that a project by funded to (1) validate through site visits and the assembling of implementation and impact data the extent to which sites already recognized represent exemplary "hands-on, minds-on" programs as defined in our reports; (2) identify additional district programs which meet these criteria; (3) profile and develop a catalog of the set of programs: (4) provide assistance to each district to develop awareness materials, training materials and procedures, visitation procedures and demonstrations, and other dissemination-related activities.

In addition we recommend that each exemplary district be provided additional funding (up to $50,000 per year) to conduct dissemination/outreach activities and provide training and implementation assistance to other districts interested in using their programs.

3. Recommendation for Alternative Forms of Research in Districts and Elementary Schools where Science is a Priority:

> We recommend that a federal funding agency support a series of case studies of schools or districts where elementary science teaching has the same priority as the teaching of language and mathematics.

One of the major problems for those concerned with scientific literacy is that science teaching simply does not have the priority in the elementary school that do other content areas. Yet there are schools and districts, such as those identified in the previous recommendation, where science is considered important enough to have sufficient funding and attention given to its teaching. In other places, communities have designated magnet schools for science, another way of giving science teaching priority, if not for every child in a district, then at least for some. Our interest here is in what factors work to make science a priority. These may include certain dimensions of the school or community context; individual advocates or roles certain individuals play, and strategies used to inform and stimulate certain kinds of decisions educators and policymakers. A set of case studies could illuminate this issue and suggest actions that could be taken by others.

4. Recommendation for Alternative Forms of Staff Development for Elementary School Science Teachers:

> We recommend that schools, districts, regional and state agencies, universities, and various funding sources experiment with different forms of

staff development for science teaching, developing new models that can enhance or even, at times, repl. ·e, excellent training workshops as the typical mode of staff development.

In the first recommendation above, we described a staff development effort that relies on the most widely researched and grounded approach: training with follow-up coaching (Joyce & Showers, 1988). Yet there are other models of staff development that have promise for promoting our vision of good science teaching, and could have other undiscovered benefits as well. These models include: 1) immersion institutes where participants learn science content and process by addressing problems such as those faced by scientist and only afterwards apply those learnings to science teaching; 2) institutes attended by cross-role teams whose goal it is to design and develop new science programs and develop internal capacity to implement them; 3) development of special teaching centers modeled on the Shenley School in Pittsburgh, where teachers are released from their teaching responsibilities for extended periods of time to study new skills and approaches in a clinical setting; and 4) training-of-trainers models, which develop internal capacity in a district or region to train and provide ongoing in-school support of teachers of science. Use of these models alone or in combination could add greatly to our repertoire of staff development approaches.

5. Recommendation for Leadership Development for Local Science Leaders

We recommend support for the development of a number of initiatives to train science leaders. Currently a leadership center is being designed by the National Science Supervisors Association to work at a national level. The National Science Resources Center is sponsoring a summer institute to develop leadership for elementary science. We suggest that similar efforts be undertaken throughout the country that are able to reach more people, and that concentrate on the development of cross-role leadership teams as well as formally designated science leaders.

With the dearth of science teaching in our elementary schools, we need more leaders who are equipped with not only science teaching skills, but with skills in training, change management, public relations, program planning, materials management, and assessment. The current trend towards shared decision making and site-based management further complicates the role of science leadership, since it involves teachers and principals in decisions traditionally made by district curriculum leaders. Thus the role of science leaders will likely be broader than it has been in the past, requiring more team-building and group process skills, and additional ways to ensure that decision making is informed by what is known about good science teaching.

6. Recommendation for Research on Shared Decision Making in Elementary Schools:

> **We recommend the funding of research that focuses specifically on alternative patterns of decision making for the improvement and maintenance of good science teaching. This research should pay special attention to current efforts in site-based decision making to examine how science is taught and the priority it is given.**

Currently there are hundreds of schools across the country that are participating in experiments in decentralized decision making, using a variety of different strategies and approaches. How and what decisions are made about curriculum and instruction are critical to the future of science education. Some science educators fear that when teachers have decision making authority, science may be lost from elementary schools, curriculum development efforts may result in collections of teachers' favorite (but tired) units, and central office support roles and responsibilities will be eliminated entirely. Such concerns raise a need for careful examination of the influence of new decision making structures on science teaching, and the contexts and conditions under which science teaching is improved and thrives.

7. <u>Recommendation for Research and Development of Effective College Coursework for Prospective Elementary Teachers</u>:

We recommend that a study be undertaken to determine indicators of effective college science and teacher preparation methods courses. We further recommend that development funds be made available for the design of additional courses that incorporate the findings of this report.

In the long run, better science teaching in schools should be supported by a supply of good science teachers coming out of teacher preparation programs. Earlier in this report we proposed that different kinds of college science courses and teaching methods courses were needed to achieve that goal. These courses would be experiential in nature, based on a constructionist approach to learning, and assist prospective elementary teachers to know and use existing exemplary materials and programs. Yet we know of very few instances where teacher preparation coursework has the characteristics we believe are necessary. Thus, a study of indicators of such courses could provide a foundation upon which to build future courses.

At the same time, we believe that enough is known about what *should* characterize such coursework that additional development work can be undertaken. While the National Science Foundation currently funds some development work for teacher preparation, we would like to see more designs that reflect our approach, and strong research/evaluation components to understand their impact.

Simultaneous to this development work, and certainly as a result of it, national, state, and regional organizations and agencies can proceed towards incorporating into their standards those requirements that promote the effective teaching of science.

8. <u>Recommendation for Strengthening of Basic Standards and Requirements:</u>

> **We recommend that state education agencies, regional and state accreditation organizations, universities, and school districts change their requirements such that (1) elementary teacher certification includes coursework in science and science methods, and demonstrated proficiency in science teaching; (2) elementary teacher assessment include assessment of knowledge, skills and behaviors required for effective science teaching; and (3) program accreditation include requirements for experiences for prospective teachers that ensure their learning of science and science teaching.**

We are well aware of how often regulations drive program design, so it is critically important that these also reflect what we know about science teaching and learning.

The two previous recommendations involve a close-in look at teacher preparation coursework and standards. The next two recommendations address teacher preparation programs more programmatically as sets of coursework and experiences that together yield a science teacher.

Teacher preparation models need to be comprehensive. They need to include newly designed science courses that incorporate a constructivist approach and treat science content deeply rather than broadly. Coursework in pedagogy should attend to the developmental needs of prospective teachers, providing a variety of increasingly intense field experiences. The use of varied assessment procedures for different science outcomes should be included. New staffing patterns are needed to support the internship and induction periods, ensuring special support by excellent mentors and reduced teaching responsibilities. All of this requires close collaboration between school and higher education personnel, and special attention to science as an important teaching area.

9. <u>Recommendation for Research and Development on Models of Teacher Preparation</u>:

We recommend that research be conducted on models of teacher preparation to better understand their influence on the various outcomes of teacher education, and the elements that are critical to their success. In addition, programs to prepare teachers in the ways recommended in this report need to be designed, developed, and evaluated for their impact.

Several teacher education programs that emphasize science for elementary teachers have been referred to in earlier chapters of this report. We need to better understand their impact, as well as to design others that have promise to change teacher preparation in the desirable ways. One kind of program that should be given special attention is the professional development school. In such settings, close collaboration between university faculty and differentiated staffing patterns for inservice teachers allow prospective teachers to learn in a real school, with models of exemplary teaching and adequate support for their development. These settings are particularly helpful for beginning teachers, although other program structures accommodate their needs as well. Teacher preparation models designed to give science equal priority to language and mathematics are needed if we are to understand how teachers can best be prepared.

10. <u>Recommendation for Dissemination of Promising Teacher Preparation Models:</u>

We recommend that promising teacher preparation models that pay special attention to science be identified, profiled, examined for evidence of effectiveness, and disseminated widely to the teacher education community. These models should include all the characteristics listed above, and should be drawn from a variety of settings, with special attention to those serving at-risk populations, both urban and rural.

Similar to our need for model elementary science programs, we need more model teacher preparation programs for universities and school/university partnerships to adopt or adapt to their own needs and situations.

11. <u>Recommendation for Nationwide Dissemination</u>:

We recommend a dissemination system for science education that will support the spread and implementation of the best science curricula, programs and teacher development strategies to support good science teaching.

A goal of our Center is to synthesize research and exemplary materials that illustrate the many dimensions of effective science education and make that information accessible to educators and noneducators alike. However, the Center's dissemination function is largely limited to production of print materials and some interactions with professional organizations in order to devise cooperative ways of reaching all the audiences interested in science education. Yet, print alone will not suffice, as we know from research on how improvements spread and are institutionalized in education systems (Berman & McLaughlin, 1978; Crandall & Loucks, 1983; Havelock, 1973).

An effective dissemination system for science education would reach many people, ranging from federal agencies and other national bodies, through state, higher education, and school district organizations, to classroom teachers. Its functions would include:

- packaging of information and materials, recommendations, and models of science teaching and learning that emanate from research, development, and special groups created to address problems in science education, for example, drawing on the new curriculum development work, the National Science Resources Center (1988), and the exemplary programs identified by the National Science Teachers Association;

- formulation of the most appropriate delivery strategies, for example, training for teachers or administrators or a combination, training of other school or district staff, awareness sessions for parents and school boards, manuals for teachers and principals, policy briefs for school superintendents and for local and state legislators;

- identification and/or development of delivery systems, for example, existing or needed organizations, agencies, networks, and interaction with them or among them;

- coordination and ongoing support of delivery, with quality control that ensures soundness of and equitable access to information, materials, and services; and

- provision of channels for informing policy makers, researchers, developers, and others concerned with improving science education of needs in the classroom as experienced by teachers and local administrators.

One possible design for a dissemination system that carries out these functions has several features. First and foremost, it is based on research that shows that dissemination promotes meaningful changes in practice when it provides a high level of assistance in an environment where support and clear expectations create pressure for change (Crandall & Loucks, 1983). A dissemination system must simultaneously develop the capability of people at several levels through staff development and ongoing support, while it works to create a context in schools, districts, and states where there are incentives, resources, and clear direction.

A second feature of a good dissemination system is that no part of it displaces or replicates the work already being done by others. Instead, it enhances their work and piggy-backs on their efforts. Related to this is the notion that every function of a dissemination system should be played out through multiple channels and should serve multiple constituencies. While this may lead to complexities in understanding the system and difficulties in drawing clean organizational charts, it ensures access.

Finally, a system designed in this way requires coordination and ongoing support in the form of infusion of new materials, ideas, and strategies deriving from all levels of the educational system, as well as problem-solving assistance. This coordination function also entails mechanisms to ensure the quality of the system's work, including equal access of all populations to the services being provided, with regular assessment of operations and impact.

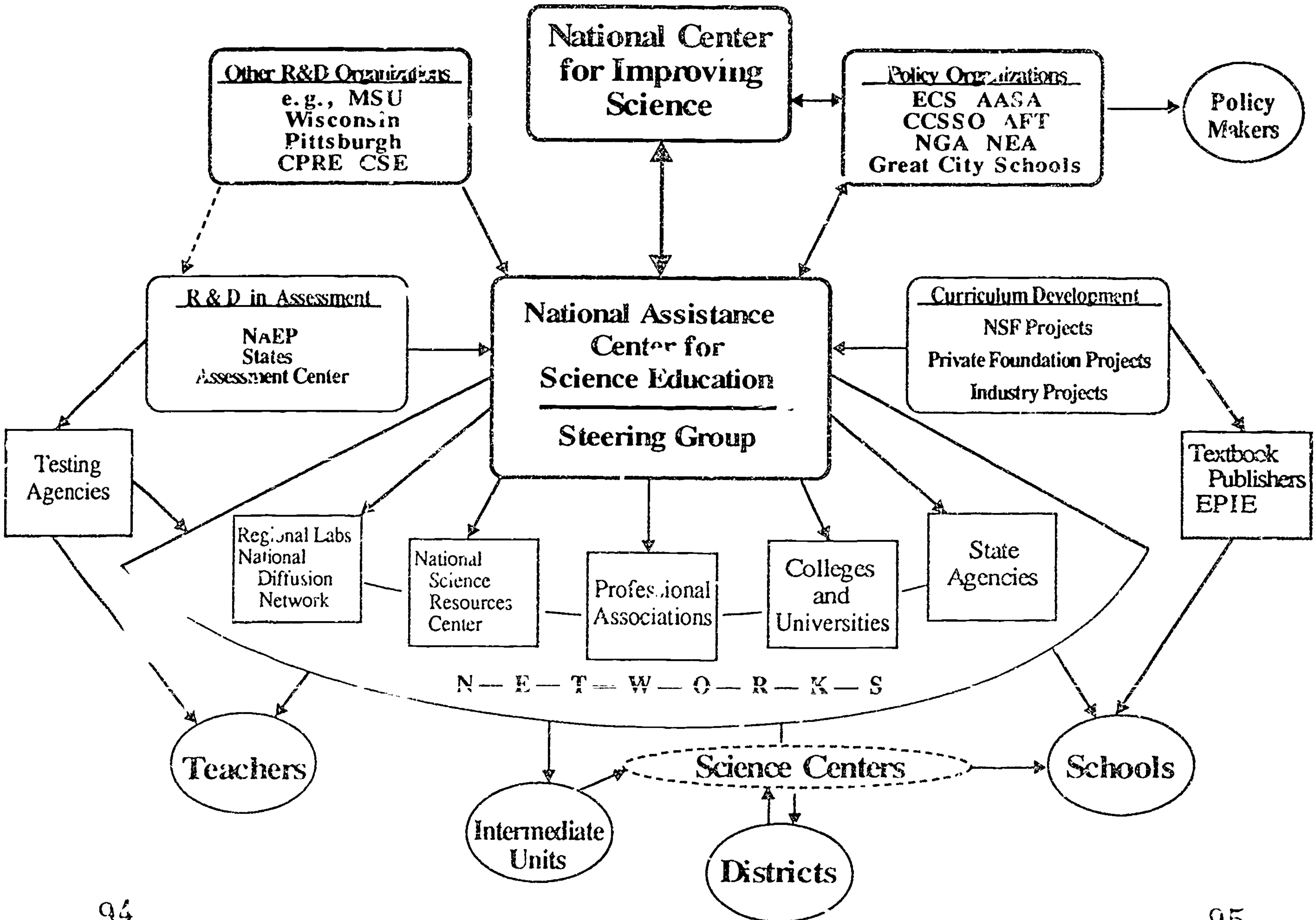
Figure 1 illustrates the structure of our design for a dissemination system. At its hub is a National Assistance Center for Science Education or a set of regional centers located throughout the country, with central coordination mechanisms. This Center (or centers) would be concerned with science curriculum and instruction, assessment, teacher development and enhancement, and improvement of the school context for science learning. The Center(s) would have primary responsibility for seeing that the functions of the dissemination system described above are carried out effectively. Assistance Center staff would solicit and evaluate input from other research and development organizations as well as individuals and special study groups. They would work directly with policy organizations to disseminate to policy audiences, with particular emphasis on the kinds of policies that would provide the direction and support needed to spark improvements in science education.

The system for reaching the practice community is somewhat more complex because of the "multiple access" design. A steering group might represent the primary service providers -- professional associations, state agencies and their intermediaries, colleges and universities, the regional laboratories, and science teacher centers that directly serve local school districts. The function of this steering group would be to advise on packaging of exemplary materials that are effective for the multiple audiences, help formulate appropriate delivery strategies, and identify and link to existing delivery structures. Assistance Center staff then would work with individual and clusters of organizations identified by the group, helping them incorporate new materials and strategies to better meet the needs and broaden the base of their constituents. Center staff also would solicit input on special needs and on promising practices emanating from the classroom to feed back to research, development, and policy groups.

Unfortunately, with the exception of science professional organizations and college science faculty, few of the existing channels and agencies designed to assist teachers and local educators have expertise in science. One obvious set of resources to be built upon are the existing science materials and those emerging from current NSF-funded

Figure 2

Structure of a Dissemination System



development efforts. In addition, there are many teacher centers which have a proven track record of maintaining excellent science programs, and operate successfully in large or small school districts, rural or inner city (e.g., Anchorage, Alaska; Mesa, Arizona; Schaumburg, Illinois; Fairfax County, Virginia) or serve a whole region within a state (e.g., Spencerport, New York; Portland, Oregon). But, unfortunately, most school districts do not have such science program support available; therefore, effort and resources will have to be invested to build capacity in other existing service agencies and institutions.

The dissemination scheme we suggest is not the only feasible one nor possibly even optimal. Our purpose here is to outline some necessary characteristics of an effective dissemination system, based on research and experience. The ultimate aim is to utilize the resources being developed at the national level to enable local science educators to select, design, and appropriately use exemplary science teaching and assessment materials and strategies.

The development and support of good elementary school science teachers is not an impossible goal. In this report we have laid out some grand schemes for its achievement, schemes that involve all the players and organizations that will need to participate if science teaching in the future is to be strong and valued. But we have also suggested some less grand schemes -- ones that take advantage of what we know now and what others are doing to make science teaching not only possible, but excellent, in today's schools. Doubtless, there are other strategies that will work equally well, or even better, and we must continue to select and act deliberately so that every child has the opportunity to learn science.

REFERENCES

Anderson, C.W.
1987 Strategic Teaching in Science. In B.F. Jones, A.S. Palincsar, D.S. Ogle, and E.G. Carr (Eds.), Strategic Teaching and Learning: Cognitive Instruction in the Content Areas. Alexandria, VA: Association for Supervision and Curriculum Development.

Anderson, C.W. and Smith, E.L.
1987 Teaching Science. In V. Richardson-Koehler (Ed.), Educator's Handbook: A Research Perspective. NY: Longman.

Arons, A.B.
1983 Achieving Wider Scientific Literacy. Daedalus, Spring:91-121.

Atkin, J.M. and Raizen, S.A.
1988 At-Risk Students. Paper presented at the Stanford University Centennial Conference, Accelerating the Education of At-Risk Students.

Ausabel, D.P.
1968 Educational Psychology: A Cognitive View. NY: Holt, Rinehart & Winston.

Beane, D.B.
1985 Mathematics and Science: Critical Filters for the Future of Minority Students. Washington, D.C.: Mid-Atlantic Center for Race Equity, American University.

Berman, P. and McLaughlin, M.W.
1978 Federal Programs Supporting Educational Change, Vol. VIII, Implementing and Sustaining Innovations. Santa Monica, CA: Rand Corporation.

Blank, R., and Espenshade, P.
1987 State Education Indicators on Science and Mathematics Washington, D.C.: Council of Chief State School Officers.

Bredderman, T.
1982 Activity Science -- The Evidence Shows it Matters. Science and Children, 20(1):39-41.

Burry, J.A., Poggio, J., Glasnapp, D.R., and McMaster R.
1988 Using Practice Profiles for Monitoring Assistance Through Assessment for the Beginning Teacher. Lawrence, KS: Center for Educational Testing and Evaluation.

Bybee, R.W.
1988 Contemporary Elementary School Science: The Evolution of Teachers and Teaching. In A.B. Champagne (Ed.), Science Teaching: Making the System Work. This Year in School Science, 1988. Washington, D.C.: American Association for the Advancement of Science.

Bybee, R.W., Buchwald, C.E., Crissman, S., Heil, D., Kuerbis, P.J., Matsumoto, C., and McInerney, J.D.
1989 Science and Technology Education for the Elementary Years: Frameworks for Curriculum and Instruction. Andover, MA: The National Center for Improving Science Education.

Capper, J.
1988 State Education Reforms in Mathematics, Science, and Computers: A Review of the Literature. Washington, D.C.: Center for Research and Practice.

Carnegie Forum on Education and the Economy
1986 A Nation Prepared: Teachers for the 21st Century. NY: Carnegie Corporation.

Champagne, A.B.
1987 The Psychological Basis for a Science Teaching Model. Washington, D.C.: American Association for the Advancement of Science.

Cole, M. and Griffin, P. (Eds.)
1987 Contextual Factors in Education: Improving Science and Mathematics Education for Minorities and Women. Madison, WI: Committee on Research on Mathematics, Science, and Technology Education, Wisconsin Center for Educational Research.

Collins, A.
1989 Curriculum Issues in Comprehensive Teacher Assessment in Science. Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Cox, P.L., Loucks-Horsley, S., and French, L.C.
1987 Getting the Principal Off the Hotseat: Configuring Leadership and Support for School Improvement. Andover, MA: The Regional Laboratory for Educational Improvement of the Northeast and Islands.

Crandall, D.P.
1983 The Teacher's Role in School Improvement. Educational Leadership 41(3):6-9.

Crandall, D.P. and Associates
1982 People, Policies, and Practices: Examining the Chain of School Improvement, Vols. I-X. Andover, MA: The NETWORK, Inc.

Crandall, D.P. and Loucks, S.F.
1983 A Roadmap for School Improvement. Executive Summary and Vol. X of People, Policies, and Practices: Examining the Chain of School Improvement. Andover, MA: The NETWORK, Inc.

Darling-Hammond, L.
1986 A Conceptual Framework for Examining Staffing and Schooling. Santa Monica, CA: Rand Corporation.

Day, J.D., French, L.A., and Hall, L.K.
1985 Social Influences on Cognitive Development. In D.L. Forrest Pressley, G.E. MacKinnon, and T.G. Waller (Eds.), Metacognition, Cognition, and Human Performance, Vol. 1, Theoretical Perspectives. NY: Academic Press.

Devaney, K. (Ed.)
1977 Essays on Teacher's Centers. San Francisco, CA: Far West Laboratory.

Fullan, M.
1982 The Meaning of Educational Change. N.Y.: Columbia University, Teachers College Press and Toronto: OISE Press.

Fullan, M.
1985 Change Process and Strategies at the School Level. The Elementary Journal 3:391-421.

Fuller, F.F.
1969 Concerns of Teachers: A Developmental Conceptualization. American Educational Research Journal 6:207-226.

Gallagher, James J.
1983 Gifted and Talented Students. Paper presented at the Science and Public Policy Seminar, Federation of Behavioral, Psychological, and Cognitive Sciences, Washington, D.C.

Garmston, R.J.
1987 How Administrators Support Peer Coaching. Educational Leadership 44(5):18-28.

Glickman, C.D.
1981 Developmental Supervision: Alternative Practices for Helping Teachers Improve Instruction. Alexandria, VA: Association for Supervision and Curriculum Development.

Goodlad, J.I.
1984 A Place Called School: Prospects for the Future. NY: McGraw-Hill.

Guskey, T.R.
1986 Staff Development and the Process of Teacher Change. Educational Researcher 15(5):5-12.

Hall, G.E. and Loucks, S.F.
1978 Teacher Concerns as a Basis for Facilitating and Personalizing Staff Development. Teachers College Record 80(1):36-53.

Harlan, W.
1985 Changing Children's Ideas and Thinking. In Teaching and Learning Primary Science. London: Harper and Row, Ltd.

Harvey, G. and Crandall, D.P.
1988 A Beginning Look at the What and How of Restructuring. Andover, MA: The Regional Laboratory for Educational Improvement of the Northeast and Islands.

Havelock, R.
1973 The Change Agent's Guide to Innovation in Education. Englewood Cliffs, NJ: Educational Technology Publications.

Heikkinen, H. and McDevitt, T.
1987 A Model Program in Science and Mathematics for Elementary Pre-Service Teachers. Greeley, CO: University of Northern Colorado.

Helm, H. and Novak, J.D.
1983 Proceedings of the International Seminar: Misconceptions in Science and Mathematics. Ithaca, NY: Cornell University.

Holmes Group
1986 Tomorrow's Teachers: A Report of the Holmes Group. Lansing, MI: Author.

Huberman, M. and Miles, M.B.
1984 Innovation Up Close. NY: Plenum.

Jacobs, H. (Ed.)
In Preparation Interdisciplinary Curriculum: Design and Implementation. Alexandria, VA: Association for Supervision and Curriculum Development.

Jefferson County School District
1979 A Principal's Handbook for Elementary Science. Lakewood, CO: Jefferson County Public Schools.

Johnson, D.W. and Johnson, R.T.
1987 Learning Together and Alone. 2nd edition Englewood Cliffs, NJ: Prentice Hall.

Joyce, B. and Showers, B.
1988 Student Achievement Through Staff Development. NY: Longman.

Kanter, R.M.
1983 The Change Masters: Innovation and Entrepreneurship in the American Corporation. NY: Simon and Schuster.

Kulik, J.A., Bangert, R.L., and Williams, B.W.
1983 Effects of Computer-Based Teaching on Secondary School Students. Journal of Educational Psychology 75:19-26

Lapointe, A.E., Mead, N.A., and Phillips, G.W.
1989 A World of Differences: An International Assessment of Mathematics and Science. Princeton, NJ: Educational Testing Service.

Lewis, M.
1988 Science Education Programs That Work. Washington, D.C.: Recognition Division, Office of Educational Research and Improvement, U.S. Department of Education.

Lieberman, A. (Ed.)
1988 Building a Professional Culture in Schools. NY: Teachers College Press.

Lightfoot, S.L.
1983 The Good High School. NY: Basic Books, Inc.

Linn, M.C., Layman, J.W., and Nachmias, R.
1987 Cognitive Consequences of Microcomputer-Based Laboratories: Graphing Skills Development. Contemporary Educational Psychology 12(3):244-253.

Little, J.W.
1982 Norms of Collegiality and Experimentation: Workplace Conditions of School Success. American Educational Research Journal 19(3):325-40.

Loacker, G., Cromwell, L., Fey, J., and Rutherford, D.
1984 Analysis and Communication at Alverno: An Approach to Critical Thinking. Milwaukee, WI: Alverno Productions.

Lortie, D.
1975 Schoolteacher. Chicago: University of Chicago Press.

Loucks, S.F. and Melle, M.
1982 Evaluation of Staff Development: How Do You Know it Took? Journal of Staff Development 3(1):102-117.

Loucks, S.F. and Pratt, H.
1979 Effective Curriculum Change Through a Concerns-Based Approach to Planning and Staff Development. Educational Leadership 37:212-215.

Loucks, S.F. and Zacchei, D.A.
1983 Applying Our Findings to Today's Innovations. Educational Leadership, 41(3):28-33.

Loucks-Horsley, S., Harding, C., Arbuckle, M., Dubea, C., Murray, L., and Williams, M.
1987 Continuing to Learn: A Guidebook for Teacher Development. Andover, MA: The Regional Laboratory for Educational Improvement of the Northeast and Islands.

Loucks-Horsley, S. and Hergert, L.F.
1985 An Action Guide to School Improvement. Andover, MA: The NETWORK, Inc. and Alexandria, VA: Association for Supervision and Curriculum Development.

McCune, S.D.
1986 Guide to Strategic Planning for Educators. Alexandria, VA: Association for Supervision and Curriculum Development.

McLaughlin, M.W.
1987 Learning from Experiences: Lessons from Policy Implementation. Educational Evaluation and Policy Analysis 9(2):171-178.

Miles, M.B.
1983 Unraveling the Mystery of Institutionalization. Educational Leadership 41(3):14-19.

Mokros, R. and Tinker, R.
1987 The Impact of Microcomputer-Based Laboratories on Children's Ability to Interpret Graphs. Journal of Research in Science and Teaching 24(4):369-383.

Mortimore, P., Sammons, P., Stoll, L., Lewis, D., and Ecob, R.
1988 School Matters. The University of California Press.

Mullis, I.V.S. and Jenkins, L.B.
1988 The Science Report Card: Elements of Risk and Recovery. Princeton, NJ: Educational Testing Service.

Murnane, R.J. and Raizen, S.A. (Eds.)
1988 Improving Indicators of the Quality of Science and Mathematics Education in Grades K-12. Washington, D.C.: National Academy Press.

National Science Resources Center
1988 Science for Children. Washington, D.C.: Author, National Academy of Sciences, Smithsonian Institution.

National Science Resources Center
1989 Science for Children. Panel presentation at the National Science Teachers Association Annual Meeting, Seattle, WA.

Odden, A. and Marsh, D.
1988 How Comprehensive Reform Legislation Can Improve Secondary Schools. Phi Delta Kappan April:593-598.

Oja, S.N.
1988 Final Report of a Three-Year Teacher Education Development-Demonstration Project. Durham, NH: University of New Hampshire.

Penick, J.E. (Ed.)
1983 Focus on Excellence: Elementary Science, Volume 1, Number 2. Washington, D.C.: National Science Teachers Association.

Penick, J.E. and Bame, M. (Eds.)
1988 Focus on Excellence: Elementary Science Revisited, Volume 4, Number 3. Washington, D.C.: National Science Teachers Association.

Purkey, S.C. and Smith, M.S.
1983 Effective Schools -- A Review. Elementary School Journal, 83:427-452.

Raizen, S.A.
1988 Increasing Educational Productivity Through Improving the Science Curriculum. New Brunswick, NJ: Center for Policy Research in Education.

Raizen, S.A. and Jones, L.V. (Eds.)
1985 Indicators of Precollege Education in Science and Mathematics: A Preliminary Review. Committee on Indicators of Precollege Science and Mathematics Education, National Research Council. Washington, D.C.: National Academy Press.

Raizen, S.A., Baron, J.B., Champagne, A.B., Haertel, E., Mullis, I.V.S., and Oakes, J.
1989 Assessment in Elementary School Science Education. Washington, D.C.: The National Center for Improving Science Education.

Resnick, L.B.
1983 Mathematics and Science Learning: A New Conception. Science 220(4):447-478.

Rosenholtz, S.J.
1989 Teachers' Workplace. White Plains, NY: Longman.

Saphier, J.D. and Gower, R.
1982 The Skillful Teacher. Carlisle, MA: Research for Better Teaching.

Saxl, E.R., Lieberman, A., and Miles, M.B.
1987 Help is at Hand: New Knowledge for Teachers as Staff Developers. Journal of Staff Development 8(1):7-11.

Schlechty, P.C., Ingwerson, D.W., and Brooks, T.I.
1988 Inventing Professional Development Schools. Educational Leadership 46(3):28-31.

Schon, D.
1983 The Reflective Practitioner. NY: Basic Books.

Shanker, A.
1988 Teachers' Union Perspective. Speech given at the School Year 2020 Conference, Sponsored by McREL and IMTEC, Snowmass Village, CO.

Shulman, L.S.
1986 Those Who Understand: Knowledge Growth in Teaching. Educational Researcher 15(2):4-14.

Slavin, R.E.
1988 Cooperative Learning and Student Achievement. Educational Leadership 46(2):31-33.

Smylie, M., Brownlee-Conyers, J., Attia, W., & Miller, M.
1988 The Glenview Public Schools-University of Illinois at Chicago Professional Development School Model. Paper presented at the Midwest Regional Holmes Group Conference, Chicago.

Sparks, D. and Loucks-Horsley, S.
In Press Models of Staff Development. In R. Houston (Ed.), Handbook of Research on Teacher Education. Reston, VA: Association of Teacher Educators and Macmillon Publishing Company.

Sparks, G.M. and Simmons, J.M.
1989 Inquiry-Oriented Staff Development: Using Research as a Source of Tools, Not Rules. In S.D. Caldwell (Ed.), Staff Development: A Handbook of Effective Practices. Oxford, OH: National Staff Development Council.

Waxman, H., Freiberg, H.J., Clift, R.T., and Houston, W.R.
1988 The Development of Reflective Inquiry in Teacher Education. Paper presented at the annual meeting of the Association of Teacher Educators, San Diego.

Weiss, I.S.
1987 Report of the 1985-1986 National Survey of Science and Mathematics Education. Washington, D.C.: National Science Foundation.

White, B. and Horwitz, P.
1988 Thinkertools: Enabling Children to Understand Physical Laws. Cambridge, MA: BBN Laboratories Report No. 6470.

Wynn, M.
1988 Transfer of Training to the Classroom by Student Teachers: Effects of an Experimental Model, Florida Southern College, Lakeland, FL. Paper presented at the annual meeting of the American Educational Research Association, New Orleans.

Yager, R.E.
1984 Toward New Meaning for School Science. Educational Leadership, December-January:12-18.

Yager, R.E. and Penick, J.E.
In Press Science Teacher Education. In R. Houston (Ed.), Handbook of Research on Teacher Education. Reston, VA: Association of Teacher Educators and Macmillon Publishing Company.

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