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AUTHOR	Loucks-Horsley, Susan; And Others
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ABSTRACT

This document is part of a second set of reports that focus on science and mathematics education for young adolescents. It addresses the salient issues of improving middle grade science education, emphasizing the importance of the teacher as learner and facilitator. If overall improvement is indeed to occur, the various parts of the system must change, but they must change in an interrelated fashion that places teacher development at the center of the change effort. Chapters include: (1) "Introduction"; (2) "Knowledge, Beliefs, and Skills of Middle Grade Science Teachers"; (4) "Organizational Context and Support"; (5) "Preparing Teachers for the Middle Grades"; and (6) "Summary and Conclusion." Lists of 81 references, the Teacher Development and Support Study Panel, and the Advisory Board Members are included. (CW)

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Susan Loucks-Horsley
Jackie Grennon Brooks
Maura O. Carlson
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National Center for Improving Science Education

The mission of the National Center for Improving Science Education is to promote changes in state and local policies and practices in science curriculum, science teaching, and 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, and develops 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.

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Foreword

This report, *Developing and Supporting Teachers for Science Education in the Middle Years*, is one in a series from the National Center for Improving Science Education. The first set of five reports, released between mid-1989 and mid-1990, focused on science education in the elementary years:

- Science and Technology Education for the Elementary Years: Frameworks for Curriculum and Instruction
- Assessment in Elementary School Science Education
- Developing and Supporting Teachers for Elementary School Science Education
- Getting Started in Science: A Blueprint for Elementary School Science Education
- Elementary School Science for the 90s

The first three reports focus on curriculum and instruction, assessment, and teacher development and support. The fourth report is a summary of the findings and recommendations documented in the first three. The fifth is a practical action guidebook that science supervisors can use to carry out the Center's recommendations. This document, Developing and Supporting Teachers for Science Education in the Middle Years, is part of a second set of reports that focus on science and mathematics education for young adolescents. The other reports in this second series include:

- Science and Technology Education for the Middle Years: Frameworks for Curriculum and Instruction
- Assessment in Science Education: The Middle Years
- Building Scientific Literacy: A Blueprint for Science in the Middle Years
- Science for the Middle Years: A Guide to Action

The synthesis and recommendations in this report were formulated with the help of the panel whose members are listed on page 80. We gratefully acknowledge the help of the many people who have supplied materials and made recommendations and suggestions for the text of the report. We also thank Michael Fullan and Allan MacKinnon of the University of Toronto—their reviews did much to help improve this report. Thanks are also due to the support of the Center's monitor at the U.S. Department of Education, Wanda Chambers.

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Chapter I

Introduction

In a recent informal survey, middle grade students were asked what their hopes were for science next year. Their overwhelming response: "To have a neat teacher." Teachers are indeed the focal point of schooling for young people — they can make or break the schooling experience. This is why they also need to be the focal point of efforts for improvement.

This report addresses the salient issues of improving middle grade science education, emphasizing the importance of the teacher as learner and as facilitator. This unique perspective is different from that of many previous reports, which have implied that if more effort were taken to change the various parts of the system — curriculum, teacher training, staff development, organizational structures and supports, local and state policy — then teachers could and would make the necessary changes to ensure an ideal middle grades science program. The message has been that if the system is good enough, then things will improve.

Our stance is different. We believe that if overall improvement is indeed to occur, the various parts of the system must change, but they must change in an interrelated fashion that places teacher development at the center of the change effort. The bridge linking classroom and school improvement is the teacher as learner (Fullan, 1990). A primary focus needs to be on helping individual teachers change their practices and beliefs. These changes can only come about through opportunities to engage with knowledge(their own, that of others in their profession, and that generated by research) within environments that foster experimentation and application of that knowledge. Broad systemic changes can create these opportunities for individual growth.

Not surprisingly, these opportunities for engagement for teachers are also what youngsters need for them to learn. So a further perspective of this report is that schools should be learning communities for all within their influence: students, teachers, administrators, community members, and so forth. Improving the quality of learning in the middle grades should mean improved learning opportunities for all.

Over the years, schools have been remarkably resistant to in-depth and profound change. While some studies of state policy implementation have shown that some changes in schools have occurred (Fuhrman et al., 1988, Anderson et al., 1987, Odden & Marsh, 1989), the changes have not been of sufficient depth to make a significant impact. Why has this been so? One view is that change has not been viewed systemically: the strategy of working on the parts while ignoring the whole has prevailed. We argue that, in order to help teachers change in needed ways, simultaneous change must occur in them and in the nature of their organizations.

History provides many examples of failed attempts to change individuals while ignoring their organizations. The early NSF institutes provided teachers with a long, intensive experience in learning new curricula and teaching strategies, which were extremely difficult for them to use once they returned to their schools. Lack of attention to the organization meant limited understanding, unclear expectations, and little if any support or continuity for the major changes teachers wanted to make. In one summary of 57 controlled studies to measure the effectiveness of three major activity-based elementary science programs [Elementary Science Study (ESS), Science: A Process Approach (SAPA), and Science Curriculum Improvement Study (SCIS)], any preliminary achievement gains for students were lost overtime when they were later enrolled in classrooms where more traditional methods prevailed (Bredderman, 1983).

Conversely, the open classroom movement is a good example of changing organizations without changing people. So much attention was paid to building schools without walls that the need to change teacher beliefs and practices was overlooked. Teachers whose expectations had always been that children learned best when facing front and attending to information provided by the teacher were totally unprepared to deal with multiage grouping, individualized instruction, team teaching, and the other innovations implied by open classroom structures.

As we focus on the need to help teachers change their practices and beliefs, it is clear that their organizations need to change also. But not separately. Rather, organizational development and teacher development must be inextricably linked to make the changes warranted by the challenges facing middle grades education.

But what are those changes? What broad new curricular emphases and directions for school design are so desperately needed? There are many discussions in the literature (Lipsitz,1984; Wehlage et al., 1989) of the multitude of problems facing young adolescents today. According to the Carnegie Corporation's recent report, *Turning Points: Preparing American Youth for the 21st Century*, fully one quarter of the nation's 28 million middle grade youngsters "are extremely vulnerable to multiple highrisk behaviors [among them, substance abuse and pregnancy] and school failure" (1989:8), and another quarter are at moderate risk. Although they have enormous potential for dramatic development of more abstract and complex thinking, improved self concept, and increased capacity for intimate relationships (Raizen et al., 1990), middle grade youngsters are ill served by their schools. Schools seldom challenge these students to use their increased thinking capabilities, take risks down new paths of learning, and work together to address problems and issues of vital interest to them. Instead, many schools are dull, lifeless places where students tackle unconnected and seemingly irrelevant curricula, develop few, if any, trusting relationships with adults, and become turned off to schooling of any kind.

There is increasing consensus in the literature about what needs to be done to improve middle grades education. Among the recommendations of the Carnegie Task Force and others (Hurd, 1987; National Middle School Association, 1986) are:

- Creation of small learning communities within schools in which teams of teachers are responsible for a limited number of students throughout their middle years;
- Commitment to a core academic program that promotes literacy in all content areas (including science), critical thinking, healthful lifestyles, and full participation as citizens in a pluralistic society;
- Provision of structures and support to ensure learning opportunities for all students, which includes eliminating tracking and promoting cooperative learning strategies, flexible scheduling, and adequate resources (time, space, materials);
- Opportunities for teachers and administrators to make important decisions about the instruction of their students, with structures for shared governance and leadership focused on creating optimal environments for learning;
- Opportunities for staff to become expert in the teaching of young adolescents;
- Involvement of families and communities in the education of young adolescents.

Each of these recommendations carries clear implications for science education, particularly at the organizational level. Yet what is required at the classroom level? The Center's Curriculum and Instruction report (Bybee et al., 1990) suggests that middle level science education pursue the following curricular goals.

- To develop adolescents' ability to identify and clarify questions and problems about the world;
- To broaden adolescents' operational and critical thinking skills for answering questions, solving problems, and making decisions;
- To develop adolescents' knowledge base;
- To develop adolescents' understanding of the history and nature of science and technology; and
- To advance adolescents' understanding of the limits and possibilities of science and technology in explaining the natural world and solving human problems.

Pursuing these goals at the classroom level requires:

- A curriculum organized to teach a set of major concepts through topics that are of interest and relevance to young adolescents;
- Combining science and technology in ways that allow students to not only learn about the natural world, but to learn the ways humans have chosen to adapt it to their needs;
- Integrating across the scientific disciplines, as well as between science and other content areas, such as mathematics and the language arts;

- A constructivist perspective on teaching and learning that provides students with ample opportunities to explore their own understanding of the way the world works and to amend and enhance their understanding through active engagement with scientific phenomena; and
- A commitment to exploring a relatively few ideas in depth, rather than treating a great many ideas superficially.

How much of a change does all of this require? In most cases, an enormous change. Although some are slowly evolving into a "middle school" model,[1] most middle grade schools today are departmentalized (Cawelti, 1988), with students commonly assigned to classes according to their abilities. Science courses are usually mini-high school courses, covering the same span of content with less depth, with a major emphasis on vocabulary development. Hands-on experiences are reserved for confirmatory labs, rather than exploration and concept building.

Instead, teachers need to work as facilitators of learning, not deliverers of knowledge. Schools need to be places that nurture critical thinking, health, and compassion, as well as academic performance — not factories whose sole responsibility is to prepare students for the rigors of high school by giving them a "mini" shot of the experience.

The kinds of changes required for ideal middle-level science education — that is, where important science learning is occurring in environments designed to meet the learning, social, and emotional needs of young adolescents — call for nothing less than what Kuhn (1962) calls a paradigm shift. These changes involve a very different way of thinking about science (as a way of "coming to know" rather than a collection of already determined facts, isolated from the contexts, inquiries, and purposes from which they were derived). This change includes viewing the teaching/learning process as one of helping students to create meaning for themselves, rather than as rote information transfer from teacher to learner. It requires changes in how the learning environment is organized, how the practice of teaching is conceptualized, and how the needs of students are perceived. Often, this shift means much more than fitting new ideas into current perspectives. This shift means adopting new paradigms, new roles from which future roles can grow, and creating entirely new perspectives on what constitutes good education.

What is required is a transformation of ways of thinking about learning, of roles and relationships, of structures and expectations. Unlike changes of the past which were more uni-dimensional — a change in curriculum, the addition of a career education program, use of a new testing program — these suggested changes are of another order — what Cuban (1988) calls second-order changes. These changes

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[1] Many of the recommendations we make in this report are consistent with the middle school model advocated by the National Middle School Association (1986) and the Carnegie Task Force (1989). We have, however, persisted in not using the term "middle school" as the organizational context for the reform of science education, since we believe that, while not optimal, many if not all of these changes could occur in more traditional junior high school settings.

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are more all-encompassing and alter the fundamental ways in which organizations are structured. They introduce new goals, structures, and roles to transform the familiar and existing ways of doing things.

The integral role of the teacher in this second-order change is graphically depicted by Figure 1. One of the intersecting circles represents teachers' existing beliefs and attitudes: how they think about learning, about students, about science, about their roles in the learning process. It also includes how much teachers value the learning of science and what kind of learning is valued (for example, facts as compared to abstract ideas).

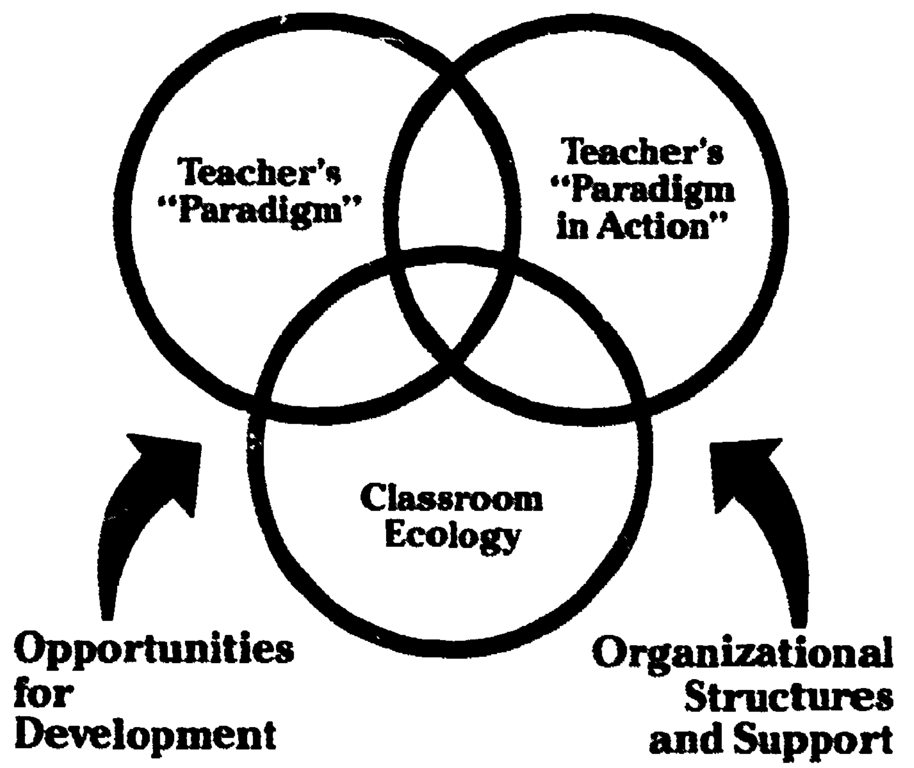

Figure 1: Important Teacher-Related Influences on Large-Scale Change

The second circle represents the teacher's practice. This includes the teacher's teaching strategies, content, materials, use of space and time, evaluation and grouping strategies. Sometimes a teacher's practice is an accurate reflection of individual beliefs (that is, there is a large area of overlap), as when the teacher believes that students are "empty vessels" and thus the teacher lectures and assigns reading to promote learning. Other times the teacher is kept in some way from acting out his or her paradigm. For example, the teacher may believe that students learn better when they do so cooperatively, yet they always work alone in the classroom. This may be because the teacher doesn't know how to set up cooperative learning groups, the principal frowns on cooperative learning (or so the teacher thinks), and/or parents have complained about students of higher ability being held back because they are required to work with less able students. In these situations there is, of course, little, if any, overlap.

The third intersecting circle represents the classroom ecology, or the kind of environment that the teacher or other forces cause to exist in the classroom. This includes the way youngsters are encouraged or not encouraged to work together, to take risks, to think deeply, to argue, etc., and the "ambiance" that may either foster a love of science and learning, or a tolerance of them, at best. It includes the norms and expectations for behavior and attitudes.

As before, there may be small or large overlap between this and the other circles. A district may institute a new emphasis on the deep study of a few ideas in science, but an individual teacher may stick closely to the old textbook (the teacher's practice), forcing the classroom ecology to be one where finishing work quickly and getting answers correct are the norm. Conversely, another district's mandate for curriculum coverage may require strict adherence to a given, traditional textbook. A teacher may not adhere to the district's demands, so his or her practice includes hands-on experiences, challenging questions, lengthy discussions, and cooperative learning groups; the ecology of the classroom reflects encouragement of deep thinking, long, thoughtful answers, and full participation by all, regardless of ability.

Our notion of the paradigm shift necessary for transforming middle grade science education includes attention to all three of the intersecting circles. Currently, there are approaches to change that focus predominantly on only one. For example, most training and curriculum implementation efforts focus on changing teacher practice; approaches such as cognitive coaching (Costa, 1985) focus on teachers' beliefs, helping them develop new views of learning and of their roles in the learning process; and strategies such as Teacher Expectations for Student Achievement (TESA) help teachers change the classroom ecology, by focusing on the quantity and nature of classroom interactions and how they influence student behavior. These approaches are all useful, especially as entry points to initiate the change. But what is required for the kind of paradigm shift we envision as necessary is a set of teacher development and support activities that will address all three circles.

How does the organizational context fit into this picture of change? As noted in the figure, the school context is the most immediate. Its nature — whether it is organized as the kind of learning community for both students and teachers described earlier — influences greatly the teacher's beliefs, practices, and classroom ecology. And the larger context — the district, community, state, and so forth — can have similar influence, both positive and negative, on the teacher.

This is the universe addressed in this report. In it we consider the following questions:

1. What do teachers need to know, believe, and be able to do to meet the science and other learning needs of young adolescents?
2. What development opportunities do teachers need in order to change or refine the knowledge, beliefs, practices, and classroom environments current research finds to be so critical to the science learning of middle grade youngsters?

3. What organizational features and structures do teachers need to change or refine the knowledge, beliefs, practices, and classroom environments so critical to the science learning of middle grade youngsters?
4. How can prospective science teachers best be prepared to participate fully in good programs for middle grade youngsters?

These questions are addressed in the report, with recommendations for action. The final chapter summarizes the recommendations.

Chapter II

Knowledge, Beliefs, and Skills of Middle Grade Science Teachers

Teachers develop skill and knowledge over years of hard work that result in what Anderson (1989) calls a complex and multifaceted "pattern of practice." He observed that one excellent teacher's pattern of practice included "the social norms and expectations that prevailed in her classroom, the kinds of work that her students did and her ways of evaluating it, the judgments that she made about what science content to teach and how to teach it, her ways of treating individual students who encountered problems, and many other facets" (1989:8). This complex and multifaceted "pattern of practice" emanates from the teacher's complex and multi-faceted paradigm. Changing teachers' patterns of practice from those that do not work well for middle grade youngsters to those that do is directly related to teachers' willingness and abilities to shift the paradigms that govern their practices.

Anderson's description closely resembles the elements of Figure 1 that involve the teachers: their beliefs, practices, and classroom ecology. While Anderson combines the knowledge, skills, and attitudes of good teachers into three areas (social and pedagogical knowledge, knowledge of science, and knowledge of students), we add other important needs that are especially important for teachers of young adolescents. Our list includes:

- Knowledge of middle grade students;
- Knowledge of science and technology content and skills in "doing" science;
- Knowledge and skills in general pedagogy, classroom management, science pedagogy, and pedagogical content knowledge;
- Knowledge of the middle school concept;
- Interpersonal and communication skills; and
- Professional attitudes and commitment.

This chapter begins with the current state of middle grade teacher knowledge, beliefs, and practices. It then describes, in detail, what teachers ought to know.

The Way It Is: What Current Middle Grade Teachers Know, Believe, and Do

It is difficult to estimate what teachers currently teaching in the middle grades know about teaching students at that level. We suspect that what they know they have learned for themselves, constructing their own knowledge base from their experiences. It is unlikely that they acquired much knowledge from their undergraduate programs, since, even as late as 1987, not even one-third of teacher education institutions in the country had programs for middle-level teachers (McEwin & Alexander, 1987). Furthermore, states, too, have come to develop middle grade teacher certification requirements slowly, with only two states having such requirements in 1968 (around the time when a substantial number of current teachers were certified to teach), 15 in 1978 (McEwin & Allen, 1985), and 28 in 1987 (Alexander & McEwin, 1988). Thus, a large proportion of the teachers currently teaching at the middle level were prepared to teach either elementary or secondary school.

Typically, teachers do not become teachers of the middle grades by choice. Many consider it a "way station" on their path to or back to either elementary or secondary assignments. This results in their disliking their work for several reasons. First, they lack confidence in their ability to teach middle level students, and their lack of success reinforces that feeling. Second, they are overwhelmed by the impersonality of many middle grade environments, where 1000 to 2000 students are scheduled throughout a day of 50-minute periods (Carnegie Task Force on Education of Young Adolescents, 1989).

Many teachers also share with other educators and parents of middle level youngsters the belief that young adolescents are incapable of complex critical thought since, at that age, the youngsters are undergoing rapid physical and emotional development. These teachers believe that minimal effort should be spent to stimulate higher levels of thought until the youngsters reach high school and "become teachable again" (Carnegie Task Force on Education of Young Adolescents, 1989). While there is no persuasive evidence to support this argument — and much to refute it (see Raizen et al., 1990) — it does in fact form the basis on which many middle grade educators teach.

The practice of middle grade teachers is influenced by the norms and structures of their organizations, as well as by their knowledge and beliefs. A large majority [66 percent, according to a recent survey by Cawelti (1988)], teach in departmentalized schools, with responsibility for one subject. They focus on content divided in 50 minute chunks, and tend to teach disconnected factual information using a lecture and discussion format with occasional laboratory activities.

Students are typically assigned to classes according to ability (McPartland et al., 1987) and teachers differentiate instruction accordingly. Teachers treat students from whom they expect less differently from those they perceive as more able. The former are often seated farther away from the teacher, receive less direct instruction, are given fewer opportunities to learn new material, and are asked to do less work. They are called upon less often and when they are, the questions they are asked are more often simple and basic than thought provoking. The students are given less time to respond and less help when their answers are wrong (U.S. Department of Education, 1986).

In departmentalized, ability-grouped 50-minute-period situations, teachers are rarely able to develop content in any depth and make students feel comfortable participating and asking questions. Teachers provide few opportunities for students to work together, rather they often see such behavior as cheating; teachers are unable to develop an understanding of the intellectual as well as the social and emotional needs of the "whole child," since they are restricted by time and type of content.

It is not clear from this description how much of teacher practice in middle grade settings is influenced by what they know, what they believe, or what their organization allows them to do. We are quite sure that rigid organizational structures can inhibit good science teaching. We assume that more progressive structures can have a positive effect. However, those who think that merely changing the organizational structure will result in excellent middle-level teaching underestimate how much teachers need to know and be able to do, and how important are a particular set of beliefs that would allow them to do so. There is no reason to believe that teachers' beliefs, knowledge, and skills are such that they could walk into an unconstrained setting tomorrow and be excellent. The teachers simply have not had the opportunities for learning in their current settings, nor the formal opportunities for learning through preservice or inservice programs.

This argument supports our discussion in chapter 1 of the importance of attending to the individual and the organization simultaneously. In the sections that follow we begin with our focus on the individual teacher by discussing what knowledge, skills, and beliefs good middle-level science teachers need. Later, in chapter 4, we return to the changes needed in the organization to support the ideal patterns of practice.

Knowledge of Middle Grade Students

Middle grade science teachers need to know about the intellectual, psychological, social, and physical development of young adolescents. They need to understand their students' individual learning styles and the implications of their short attention spans (Padilla et al., 1988). Teachers need to understand the nature of normal adolescent social and emotional development, particularly these aspects: mood swings and emotional outbursts, sensitivity to criticism, self-preoccupation, group relationships and peer approval, challenge of adult authority, awareness of the opposite sex, and need for an accepting and supportive environment (Padilla et al., 1988). In addition, teachers need to be aware of young adolescents' rapid physical growth and development.

With so much happening daily in the lives of young adolescents, their teachers need to understand the tension between intellectual and academic priorities and the emotional and social dimensions of adolescence. This is a tension students and teachers face every day (Superintendent's Middle Grade Task Force, 1987). More and more teachers also need to understand cultural differences and how they affect the development of the young person.

General knowledge of adolescent intellectual development is helpful, but knowing how students think about and learn science and specific science topics is vital for the science teacher (Anderson, 1989). According to Anderson, to understand science meaningfully, students have to connect scientific knowledge with their own personal knowledge of the world. They have to go through the complex process of conceptual change, restructuring and integrating their personal knowledge with scientific knowledge. This is equally true of learning about technology. The teacher needs to know this process well to guide students through it.

Typically, students begin to construct formal operational schemes during the middle grades. Such a transition means that students, when asked to solve problems and think about science concepts, will use both concrete operational schemes, and beginning or advanced forms of formal operational schemes. How students approach the transition depends upon their familiarity with the material, their level of self esteem, the skills necessary to understand and complete tasks, and other related factors. Teachers must understand concrete and formal reasoning patterns and the significant implications of such knowledge for curriculum development and the organizational structure of schools.

Knowledge of Science and Technology Content and Skills in "Doing" Science

Middle grade science teachers need a strong foundation in the concepts and principles of science, across the science disciplines. The Center's report on curriculum and instruction (Bybee et al., 1990) describes the ideal middle-level curriculum as based on major concepts of science and technology, taught through topics of high interest to young adolescents which more often than not incorporate more than one scientific discipline (life, physical, earth, space). The major concepts are: cause and effect; change and conservation; diversity and variation; energy and matter; stability and equilibrium; models and theories; scale; structure and function; systems, subsystems, and interactions; and patterns, rhythms, cycles, and symmetry. Middle-grade science teachers need to understand these concepts and know how they are illustrated by the basic principles within each of the scientific disciplines.

Knowledge of the fundamental principles of science and technology is particularly important for middle-level teachers as they work to integrate curriculum across content areas. Without a fundamental knowledge of science and technology, teachers cannot make appropriate adaptations in their instruction to incorporate other content. For example, substituting reading and writing about scientific phenomena for hands-on activities, in the name of integration, undermines science and technology learning.

Middle grade teachers also need a basic grounding in the principles of health education, because it is an important element of the middle grade curriculum, and science teachers are often responsible for teaching it (although they also share that responsibility with social studies and physical education teachers).

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To teach science and technology effectively, teachers also need a thorough understanding of the scientific process. They need to understand the nature of science as "a process that can organize and explain reality and provide a basis for predictions about the future" (Padilla et al., 1988:8) and the nature of technology as helping solve problems of human adaptation (Bybee et al., 1990). Teachers need to be able to demonstrate science laboratory skills (such as measuring with a variety of tools and using a microscope), science-related intellectual skills (such as generating hypotheses and designing experiments) and generic thinking skills (such as problem solving and reasoning). They need to have scientific habits of mind such as a desire for knowledge, skepticism, and honesty.

Finally, science teachers need to understand the relationship of science and technology to society (Padilla et al., 1988). They need to understand ways in which science has changed society's view of the world, the ways in which society affects science, and the three-way relationship of science, technology, and society.

Knowledge and Skills in Science Pedagogy, General Pedagogy, Classroom Management, and Pedagogical Content Knowledge

Anderson (1989) makes an interesting distinction between knowing science and knowing science to teach it. He argues that there are two different subcultures involved: that of scientists and their work and that of students. To enable learning to occur, the teacher has to transform science, selecting a body of scientific knowledge and a version of the scientific subculture that are accessible to students. Acting as mediators between thetwo subcultures, teachers, science educators, curriculum committees, and state curriculum leaders have to decide what is essential to the scientific enterprise and what is peripheral, which aspects of scientific thought and language are accessible to their students and which are not, and how much of the technical language of science can be sacrificed for student understanding, without diminishing their grasp of important principles. Being able to perform such complex thinking and reasoning requires that teachers have a firm grasp of science, both content and process.

A teacher can know an enormous amount of science, but without the ability to help students use scientific knowledge as a tool to make sense of the world around them, good teaching (or learning) cannot occur. Teaching science requires that teachers know how to arrange and manipulate the learning environment in such a way that students can construct their own knowledge of scientific principles. Thus, the key word is construction, not instruction. This includes the ability to help youngsters articulate their concepts of scientific and technological phenomena, making them aware of certain common "misconceptions" that are apt to be held, and tailoring teaching strategies to the particular conceptions that students hold. Teachers can then create learning experiences that will demonstrate the scientific principle in a way that helps students enlarge or change their concepts.

Promoting conceptual change requires that teachers have a large repertoire of strategies that involve active learning by all students. One such strategy is cooperative learning, which helps teachers effectively teach students of diverse abilities and different rates of learning, at the same time that it promotes the development of social skills and behaviors. Teachers need to enrich the variety and depth of learning activities through the use of family and community resources.

Middle level science teachers must be able to organize and plan science lessons, units of instruction, and long-term curricula. They need to know what curricula and science programs are available nationally as well as locally and how those might be adapted to the needs of their particular students. If an important dimension of the middle grade program is an integrated curriculum that builds from year to year, then science teachers need to be able to identify and develop interdisciplinary curricular themes, and to work with other teachers to coordinate the organization of learning activities. Their day-to-day lessons need to be appropriate to their students' interests and level of thinking.

Teachers need to know how to stimulate and encourage the use of higher order cognitive skills and to promote a spirit of inquiry and stimulate students to think about and communicate ideas. They need to be able to help students learn how to solve problems, and to prepare them for present and future learning.

Teachers also need to have knowledge of different forms and purposes of assessment. They need to know how to assesses different levels of knowledge, as well as skills and scientific habits of mind (Raizen et al., 1990). They need to be able to design and routinely use assessment tools that are indistinguishable from learning tasks.

Middle grade teachers need to be masters of classroom management. Management is different for inquiry-oriented science than it is for teacher-directed information transfer. Teachers need to have routines that are carefully patterned to prevent disruptions, as well as a variety of preventive maintenance behaviors (Roueche & Baker, 1986). They need to know how to keep students continuously and actively engaged, and avoid wasting time on unimportant activities. They need to be able to perform time-conserving functions such as planning classwork, communicating goals, and regulating learning activities.

Knowledge of the Middle School Concept

In an effort to humanize and personalize the environment to better meet the cognitive, social, and emotional needs of young adolescents, many schools are moving to a middle school concept, which is structured to resemble small communities of learning, with a family kind of closeness. A team of teachers is given responsibility for a certain number of students with whom they remain throughout the students' middle grade careers, or throughout an entire academic year. The team is responsible for collaboratively planning students' school life, overseeing schedules, curriculum, student assignments, and assessing progress. Each student has an adult advisor to assist with both academic and nonacademic concerns.

As increasingly more schools adopt the middle school concept, teachers need to know the philosophy and rationale behind the middle school organization, and understand their various roles (for example, that of learning facilitator, student advisor, team planner). They need to be able to communicate these roles to students, families, and the community. They also need the skills to participate fully in the team structure. (See next section.)

Interpersonal and Communication Skills

Teachers of middle grade students need well honed communication and interpersonal skills so that they can work well with their students, their students' families, their colleagues, and the community. The human skills needed to work well with students include those related to group dynamics, principles of motivation, the sociology of change, systems of reward and affirmation, group cohesion, collaborative planning, the dynamics of innovation, multicultural and linguistic influences, conflict resolution, and peer group relationships. With their students, teachers need to be active listeners. They need to build rapport by showing students respect, treating them firmly and trusting them, showing empathy, and setting high expectations (Superintendent's Middle Grade Task Force, 1987). They must have some knowledge of the principles of guidance so that they can serve as advisors for students.

Teachers also need to be able to work with families of diverse backgrounds, make-up, and economic level. They need to know how to encourage families to play active roles in the education of their youngsters, finding meaningful ways for them to be involved in the school. Teachers also must know how to keep parents informed, including how to conduct parent conferences, and how to plan with them for the student's optimal course of study.

Middle grade teachers must be able to work as members of interdisciplinary teams who collectively allocate budget and space for their assigned students, choose instructional methods and materials, identify and develop interdisciplinary curricular themes, schedule classes, and evaluate student performance in light of school-wide objectives. They need problem-solving and decision-making skills and need to know how to resolve conflicts and run efficient, productive meetings. These same skills are useful since teachers participate in school-wide governance structures.

Middle level teachers also need the skills to work closely with noneducators, those who provide health and other services to meet the needs of individual students. Teachers need to be able to work with the community to set up youth service opportunities, which are becoming more and more a part of the middle school experience.

Professional Attitudes and Commitment

Teachers of young adolescents need to possess some qualities that are difficult to measure, but nonetheless vital to their effectiveness. As Blosser (1986) summarizes, they need to be flexible and enthusiastic, have a sense of humor and exercise patience.

Roueche and Baker (1986) note that exemplary middle grade teachers have a strong commitment to their work and to their students. They not only demand achievement, but provide opportunities for it. They are committed to their students outside of class, viewing them as whole individuals worthy of their respect, and operating in a broader context beyond the classroom. Exemplary teachers have their own personal goals and have determined a course of action for attaining them. They stay professionally enthusiastic, getting their rewards when students exhibit understanding and achieve their goals. They actively seek innovation.

These six areas of knowledge, belief, and skill: knowledge of middle grade students, knowledge of science and technology content and skills in "doing" science, knowledge and skills in science pedagogy, general pedagogy, and classroom management, knowledge of the middle school concept, and professional attitudes and commitment — portray an ideal teacher of middle grade science. Yet few current teachers have had the opportunities to develop fully in all areas, nor have current teacher preparation programs graduated students with these skills and knowledge. In the next chapter of this report we address the question of how to provide necessary and appropriate staff development opportunities; in chapter 5 we return to the issues of teacher preparation.

Chapter III

Staff Development for Middle Grade Science Teachers

The purpose of staff development is to help teachers acquire the knowledge, skills, and beliefs described in the previous chapter. While we know staff development alone cannot achieve this outcome, when coupled with the right organizational characteristics and supports, there is a very good chance that such change will occur.

To achieve this purpose, staff development must be a dynamic process, one that is continuous and constantly changing. The process of inquiring into the nature of scientific phenomena keeps scientists at the leading edge of their profession. Likewise, *teaching* the process of scientific inquiry best occurs at the leading edge of the teaching profession, in the classroom, where new information and new questions arise each day. People and ideas are in constant evolution. Yet, too often in the past, teachers have been treated as "empty vessels," who, once filled with the "right stuff," would perform their teaching duties with fidelity until the next new concept of the "right stuff" was poured in. Knowledge of good pedagogy came from outside of teachers and their experiences.

Recent cognitive research (Resnick, 1989), as well as research on adult learning and change (Fullan, in press; Levine, 1989; Lieberman, 1988), concur that this is not the way meaningful learning occurs. One way to think about how it does occur is to consider what teachers should be able to do in their classrooms. We believe that they should be able to successfully create and implement cognitively appropriate and socially responsive curriculum, using techniques and mediation strategies consistent with the developmental needs of their students. Teachers must be constructors of pedagogy, a task which is complex and multifaceted. It is not one they can learn to do through simple information and skill transfer formulas.

Staff development opportunities must mirror the kind of learning opportunities teachers are encouraged to provide for their students. Staff development must encourage teachers to make sense of their experiences, to construct their own meanings from new information, and to form theories that help explain the world. When the process is done well, these theories lead to curriculum and instructional strategies appropriate for students. Thus, our perspective on staff development comes from the same roots as our perspective on student learning: cognitive development requires that learners construct their own meanings and explanations for the way things work, whether it is how a plant "eats" or how young people learn science — a constructivist perspective. Current understandings and knowledge must be taken into account and used as a foundation for extending concepts or constructing new concepts for both student learning and staff development.

In this chapter we consider how educators can make the paradigm shift to the kinds of staff development that incorporate new knowledge about how learning takes place. We do so by first discussing the content of staff development in science teaching, then some staff development principles and approaches. We then use case studies of two teachers' very different staff development experiences to illustrate principles of good staff development and weave a set of recommendations about designing meaningful staff development for middle grade science teachers into our discussion of the case studies.

The Content of Staff Development

Referring to the list of teacher knowledge, skills, and beliefs discussed in the previous chapter, good staff development opportunities help teachers:

1. study the characteristics and needs of middle grade students, appreciating their students as constructors as well as recipients, of knowledge,
2. increase their understanding of science and technology and ways of "doing science,"
3. analyze the cognitive demands of science and technology concepts and create or choose curriculum and instructional strategies geared to their students' cognitive abilities,
4. reflect on their underlying attitudes and strengthen their commitments to middle level principles,
5. develop or refine their interpersonal, communication, and classroom management skills.

Staff development opportunities can be designed to directly address these areas and can focus on the nature of middle level students and how they learn, with special attention to how curriculum can be developed to address students' individual needs. Other staff development opportunities can focus on particular instructional strategies that are useful for middle grade youngsters, such as the techniques and classroom practices associated with cooperative learning. Development of skills that will help teachers work better with young adolescents, with other teachers and administrators, and with parents (such as conflict resolution, problem solving, decision making) can also be the focus of staff development.

Another important category of staff development content is knowledge of scientific concepts. In order for teachers to skillfully help their students uncover their misconceptions, the teachers must have previously uncovered their own. The reality is that many teachers harbor significant misconceptions about the very content they are teaching. Therefore, staff development must include opportunities for teachers to learn about such topics as light, optics, plant life, reproduction, biodegradation —becoming knowledgeable across several science disciplines rather than just the one they may have been prepared to teach. An additional content focus for staff development is technology — not just the use of microcomputers, as this term usually implies, but the adaptations made by humans to better live in their environments.

Teachers have few opportunities to learn about technology, per se, and it may be through a modified engineering course that the topic can best be treated. Teachers also need opportunities to explore the major concepts of science and technology recommended by The Center's curriculum and instruction panel (see Bybee et al., 1990) they need to be familiar with various science topics and how the developmental level of students influences how the topics should be addressed.

Approaches to Staff Development

Good staff development based on a constructivist view of learning is a continuous process, sustained over a period of time, and offering choices and opportunities for implementation. Teachers must be able to develop strategies that will permit them to become aware of their students' ideas and current understandings about natural phenomena and scientific concepts. They must further take their students' ideas into account in developing the instructional program, to build on or extend their students' concepts and understandings. Teachers should have opportunities to plan their own programs for growth, based upon their interests and developmental levels; districts and schools should offer development opportunities to enhance district and school goals and meet teacher needs.

Typically, staff development is equated with inservice workshops, which are more often than not one-shot experiences unconnected to the everyday work of teachers and the contexts of their schools. According to Loucks-Horsley et al. (1987), effective staff development programs nurture professional growth in an ongoing way, while creating support structures in schools and districts to help teachers maintain and refine their learning. According to these authors, effective staff development programs:

- are collegial and collaborative, providing opportunities for staff to work together in meaningful ways;
- encourage experimentation and risk taking;
- incorporate knowledge bases on effective learning, teaching, schooling, and organizations;
- involve participants in goal setting, implementation, evaluation, and decision-making;
- provide for leadership and sustained administrative support;
- build in time to participate in growth opportunities and assimilate new learnings;
- provide appropriate and adequate incentives and rewards;
- have designs based on principles of adult learning and the change process;
- integrate individual, school, and district goals; and
- are formally placed within the philosophy and organizational structure of the school and district.

Staff development programs with these characteristics go far beyond traditional inservice workshops. While carefully constructed training approaches are one option, there are other approaches that have these characteristics and can contribute to teacher growth. Sparks and Loucks-Horsley (1990) have identified five such approaches to staff development: training, observation and assessment, inquiry, curriculum and program development, and individually guided staff development. Appropriate use or adaptation of these approaches can provide the framework for good staff development for middle level science teachers.

The *training* approach is most frequently equated with staff development, but it rarely includes all the components needed to be effective. These components are: (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 classroom with feedback on performance. Because of the need for guided practice "back home," good training necessarily takes place over time and fosters meaningful collaboration on the part of its participants. This approach is also the soundest in terms of its research base; there are clear indications that its use can result in demonstrable changes in students (Joyce & Showers, 1988).

The *observation and assessment* approach involves the careful observation of teaching, with particular attention to certain behaviors, and an open discussion of observations. 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 and ways of achieving them set. The model involves clinical supervision and coaching. As a form of supervision, this approach has received much attention for its potential for formative rather than 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).

The *inquiry* approach incorporates such practices as action research and reflective inquiry; as such, it is highly attuned to the constructivist perspective. 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. This approach is based on the work of Schon (1983) and others (Sparks & Simmons, 1989).

Another approach to staff development is the involvement of teachers in the *development of curriculum and/or programs*. Teachers begin with a problem or challenge, for example, the curriculum is outdated, needs review, is not being used: student achievement and/or enthusiasm for science is low. Teachers, usually as a coordinated group, then gather information, materials, and other resources, consider existing knowledge about effective science teaching and learning, and develop and implement a solution.

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

Schools or districts can and often do develop their own staff development programs that incorporate features of some or all of these approaches, or they modify a particular approach to suit their own needs. The following case studies illustrate different adaptations of the approaches, providing examples of good staff development opportunities for middle grade science teacher development. These are highlighted along with recommendations and guiding principles for improving staff development

The Process of Professional Growth: Two Case Studies

The following vignettes illustrate the use of different staff development practices for helping teachers develop the knowledge, beliefs, and skills they need to teach middle grade science well. They also emphasize the point that learning opportunities for teachers must reflect what is known about how people learn. We know that in-depth scientific understanding is (1) the result of multiple, active experiences that challenge an individual's existing thought patterns; (2) the result of individuals making sense of their experiences; (3) dependent upon prior learnings and concepts; and (4) a time-consuming process that cannot be hurried (Duckworth, 1987). We also know that the same is true about learning to teach science (Lampert, 1984; 1985). Therefore, staff development opportunities must incorporate the same multiplicity of experiences that teachers are encouraged to offer students.

The following vignettes follow two skillful middle grade science teachers as they engage in the process of their own professional development, refining their skills and broadening their visions.

Mr. Jackson teaches seventh grade life science and mathematics in a school district whose articulated goal is to integrate child development theory into all classroom practices and inservice opportunities. The district is small, highly de-centralized, with neither department chair positions nor mandated curricula, but with clear expectations that teachers create their own curricula as a function of student need.

Ms. Fithian teaches seventh grade life science in a highly heterogeneous school district whose articulated goal is to improve the academic achievement of all its students through appropriate educational experiences. The district is highly centralized and has a well developed, supported middle school science curriculum which was planned, piloted, and modified by teachers. Numerous staff development opportunities are provided by the district for its teachers.

Both Ms. Fithian and Mr. Jackson are committed to achieving their respective districts' goals. Their school districts view staff development as more than simply taking courses. Teachers learn from a number of different sources and approaches.

They work with colleagues and have the opportunity to reflect jointly and separately upon their training. There are a variety of incentives that motivate teachers to both plan and participate in staff development. Mechanisms for applying their learning from various sources (workshops, courses, self study) are built into their staff development programs. All of these approaches are illustrated in the vignettes.

Mr. Jackson's Integration of Child Development Theory Into the Classroom

*Mr. Jackson and Ms. Trautman are partners in their school district's seminar series on cognitive development, for which all participating teachers receive inservice credit. The course helps teachers meet the district's expectation that they will use cognitively appropriate curricula in their classrooms. A teacher of gifted students in the middle school, Ms. Trautman recently found two books in the school library: **Bet You Can** and **Bet You Can't** by Vicki Cobb and Kathy Darling. She shared them with Mr. Jackson and they both thought that the physical challenges or "dares" made in the books could form a good starting point for their human body unit of the seventh grade science curriculum. They decided that they would fulfill their assignment for the seminar series with an analysis of the reasoning abilities demanded of students by selected activities in the books. Through their analysis, they concluded that the concepts embedded in the books both challenged the students and provided a practical, yet sometimes whimsical, link to the concepts being studied in their human body unit. For example, grappling with the challenge: "Bet you can't look up and close your eyes!" could be the basis for a lesson on muscle use and muscle fatigue.*

Jointly analyzing the curriculum ideas provided an important opportunity to better understand and respond to the needs of their students and to see the potentials of the concepts. The teachers discovered that two probing minds were better than one at structuring creative learning environments. Selecting how to use these activities provided another important learning opportunity. Both teachers were reminded of a significant element in the thinking and functioning of adolescents: heightened egocentricity. They smiled as they remembered a lecture they had attended the previous month on adolescent development and as they remembered all the articles they had read on the topic as part of their seminar series. In fact, last year's course on child development helped as well, for it focused on the decentering process. It was their experience in the context of the class activity that consolidated their understanding and guided their practice.

*The **Bet You Can** activities generated class discussions directly related to major concepts of science. Students were able to relate structure and function (What happens to a tennis ball cut in half and turned inside out?); understand scale (Can the length of the arm from the elbow to wrist predict your foot length?); and search for root causes (Why can you hang a spoon on the end of your nose?). Of interest to teachers, however, was that the same students, when exploring the **Bet You Can't** activities, did not demonstrate the same depth of reasoning.*

When challenged with "Bet you can't crumple a sheet of newspaper into a wad with one hand," several students were determined to beat the challenge, *even if it meant surreptitiously pressing it against their bodies or using two hands when they thought no one was looking. Although some of the students saw relationships between the size of the hand and the size of the newspaper and generated the idea that to compress a sphere, pressure must be exerted over most of the surface, many of the students who had demonstrated an understanding of scale and were able to relate structure and function in previous tasks, failed to do so in this activity. Ms. Trautman and Mr. Jackson concluded that the students' increased egocentricity interfered with their intellectual functioning. The students wanted so much to be "right" that they couldn't listen to the theoretical arguments of their classmates. Ms. Trautman and Mr. Jackson learned that to challenge a student's intellect at the leading edge of his or her development, they couldn't challenge his or her sense of competence or physical prowess at the same time.*

This segment illustrates several features of a good staff development program. It is continuous and sustained over a period of time. It starts from where the teacher is in terms of knowledge, skills, and beliefs, and provides opportunities for growth. This calls for more than one-shot workshops, but rather programs of study that extend over a period of time and may include a series of training sessions with coaching in between, seminar or support group sessions, and so forth. Mr. Jackson is working in partnership with a colleague, Ms. Trautman, in the context of a seminar series that lasts throughout the year. The series is an extension of a more formal course in which he previously participated. He keeps abreast of current literature related to the district's concern with child developmental theory.

Recommendation:
Staff development should be continuous and ongoing.

While participation in training in certain basic teaching strategies (for example, cooperative learning) should be expected of all teachers, there should also be opportunities for teachers to pursue their interests and personal goals. Mr. Jackson is able to choose among a variety of staff development options. The curriculum analysis work is earning him inservice credit that will apply towards salary increases. Teachers need options that are appropriate for their career stage, their current knowledge or skill level, and their level of comfort or concern with their teaching assignment. This calls for multiple options within staff development offerings.

Recommendation:
Teachers should have opportunities to choose among staff development opportunities that match their interests, stage of development, and competence.

This staff development program also provides opportunities for teachers to work together and examine their practice. Mr. Jackson and Ms. Trautman jointly reflected

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"In a certain population, two-thirds of the men are married, while three-fifths of the women are married. What fraction of the population is single?"

Mr. Jackson and several of his colleagues are still discussing this problem. Several years ago, two professors from a nearby university ran a six-week seminar for middle and high school teachers and administrators interested in the constructivist approach to science teaching. They gave the participants problems to solve and refused to reveal the correct answers, even in the face of ever-increasing frustration. However, the workshop instructors did illustrate and share the rotating listener/problem solver model they use in their classes. In it, participants worked in dyads on problems similar to the population question previously presented, explaining their thinking aloud to their partners. The listener's responsibilities were to concentrate on following the thinking of the problem solver and to pose questions and contradictions designed to help the speaker think more clearly about the issue. For the next problem, the two people changed roles. Trying to genuinely understand the problem-solving process of another person leads the listener to new approaches and having someone ask questions directly related to steps in solving a problem leads the problem solver to greater depths of understanding. Each participant was then asked to try the technique in the classroom and report back to the group.

on their plans to introduce a new approach to the curriculum; they analyzed the new approach; they tried it out in the classroom; then, they analyzed their results through the same developmental lens they had used to scrutinize their original analysis. The teachers and administrators in Mr. Jackson's district are constantly involved in the development and assessment of their programs. Teachers do not operate as well as Mr. Jackson and Ms. Trautman without enlightened administrators who create settings based on dialogue, mutual respect, and negotiation. Good staff development encourages teachers to be change agents — determining student needs and meeting them. Thus teachers must work closely together and work with new information gained from research, from the practice of others, and from data gathered in the classroom. Proper staff development empowers teachers to actively participate in making their classrooms and schools better places for learning by giving teachers new knowledge, tools, and opportunities to practice, to experiment — to improve.

Recommendation:

Staff development should provide opportunities for teachers to examine and reflect on their practice and on their schools, and work together to formulate new and better learning opportunities for their students.

Mr. Jackson's district staff development program also supports two of the primary purposes of staff development for science teachers: to help them further their understandings of scientific concepts and of the pedagogy associated with teaching those concepts. Mr. Jackson remembers a critical event of his professional growth when he learned a specific classroom strategy while at the same time developing a deeper appreciation for the beauty of science and mathematics. The vignette at left describes an inservice course designed for secondary science teachers only, as opposed to other inservice offerings in which teachers across the grade span work together. As teachers struggled with finding the correct answer, the strength of sharing alternative concepts emerged quite naturally, a scenario that teachers try to encourage in their classrooms.

Participants in this course gained both a rich intellectual experience and a practical strategy to try in their own classrooms.

Understanding cell theory requires abstract reasoning, and learning the many terms for cell components and processes requires extended memory space. The biochemical interactions of cell structures are highly complex — many of them not yet fully understood by those who study them professionally. In most seventh grade life science textbooks, however, students are asked to diagram, label, and define endoplasmic reticulum, mitochondria, vacuoles, ribosomes, and other cell structures. Although most seventh graders can tell you that the mitochondria are the powerhouses of the cell, how does that information relate to anything else they know? What is the context within which this information is meaningful?

Mr. Jackson and another colleague,

Mr. Smith, are trying to answer these questions. They applied for and received a small mini-grant for research awarded by their school district. Their answer to date: for most middle grade students, knowing that the mitochondria are the powerhouses of the cell doesn't mean much. Mr. Jackson and Mr. Smith then wondered if they ought to skip cell theory completely since it didn't appear to have much significance for their students. In reflecting on this possibility, they asked themselves: what might be the precursors necessary for seventh graders to understand the structure and function of cells?

The teachers decided to allow their students to discover similarities and differences among common cell types within food. They presented their students with microscopes, and with iceberg, Bibb, and red leaf lettuce, as well as onions, apples, leeks, and other vegetables and fruits. Their students' prior indifference turned into questions and surprises. "I can't believe it. Each little lettuce cell looks like the whole lettuce," exclaimed one young girl. Another student agreed and asked if that's true of other vegetables. Soon, most of the students were trying to find out. What relationships did the students discover? They discovered that variables such as color, shape, and structure on the macro level had correlates on the micro level and they wanted to know if that was always true. Each made plans to bring in different food or plant types the next day. The teacher made plans to mediate the experience by asking the students to answer the question: Are cell shape and color, and the structural patterns among cells, consistently related to the shape, color, and integrity of the whole vegetable or fruit?

What makes this type of lesson valuable? Classification, causal reasoning, and correlational reasoning are all important types of thinking for students in the middle grades. Classification is becoming consolidated and causal and correlational reasoning are beginning to emerge during this age range. This lesson fostered the growth of these types of reasoning, as well as the attitude that science is all around us, not only in a laboratory. This lesson is also a precursor to more advanced lessons in which cell structure and function can be explored. Every class was different and, the way Mr. Jackson structured his, he and his students discovered more about cells on that day than ever before.

At this point in his career, largely as an outgrowth of his participation in the school district's on-going staff development program, Mr. Jackson rarely used the science text. This is a significant change for him. In the past, the textbook was the primary source of learning and student questions were supplemental. Now, student questions are primary and the text is supplemental; it assists students in researching the questions they ask. Mr. Jackson still uses most of the traditional units found in a typical seventh grade life science text, but the units are explored in a qualitatively different way.

In the example above, Mr. Jackson has the opportunity to work with yet another colleague on a self-initiated curriculum revision effort aimed directly at new instructional approaches for a complex set of concepts. With a competitive mini-grant from his school district, he and another teacher established a common goal and, with self-determination and the financial and material support from the school district, pursued their quest.

This scenario illustrates how staff development efforts can fulfill the goals of helping teachers learn to discern the embedded cognitive demands of the scientific concepts they teach and, when those demands are too complex for their students, to choose the appropriate precursor concepts, using a constructivist perspective on the acquisition of knowledge. When it was clear that the intended curriculum was too abstract for the students, Mr. Jackson found a less abstract, qualitatively different, but equally rigorous aspect of the curricular topic to examine. Instead of asking the students to reason correlationally on the microscopic level, he carefully selected materials for the lab. He wanted to see if that level of thinking would emerge on the macroscopic level. When it did, indicating a developmental readiness on the part of those students who demonstrated it, he re-worded their own questions as the basis for the next lesson. For some students, the "original" curriculum may now be appropriate. In this staff development example, Mr. Jackson experienced firsthand the approaches to learning he needed to use with his students. He and his colleague had ample opportunities to discuss and negotiate their curriculum development efforts into meaningful learning situations for their students.

Recommendation:

Staff development should model the constructivist perspective on learning.

The following vignette from Mr. Jackson's experiences illustrates further the collaborative nature of teachers' roles, and shows each of the four recommendations in action.

As September approaches, Mr. Jackson is getting ready for school, but this year he is neither preparing his classroom, nor looking over class lists. He's anxious about his one-year assignment as Curriculum Associate, a rotating position created several years earlier in the district to help teachers work through, together, the problems of implementing constructivist-based teaching. The first few teachers to hold this position reported that, although classroom teachers readily accepted the concepts presented in the seminar sessions, their interactions with students changed little. It takes time, and support, to move from awareness to behavioral change. One of Mr. Jackson's tasks this year will be to work as a coach in classrooms, helping teachers integrate their new concepts about cognitive development and constructivism into their teaching practices.

As teachers expressed greater needs to study constructivism within the context of particular subject areas, the Curriculum Associate position began to rotate through subject areas. This year, the district's focus is on science.

Early on, Mr. Jackson formed a study group of ten middle school teachers interested in examining and restructuring their science curriculum in greater accordance with constructivist principles. He asked Ms. Williams, a high school chemistry teacher who has been working to reformulate her Honors level chemistry class, to share some of her curricular adaptations with the study group. Ms. Williams shared a lesson and lab on solubility that had yielded much greater understanding and performance from *her students. At the beginning of the lab, Ms. Williams gave her 11th graders Hershey Kisses to melt in their mouths while she timed how long it took the kisses to melt. After all the Kisses were dissolved, the group talked about the variables that might account for the differences; movement of the tongue, previous food intake (hot coffee or cold soda), and chewing were suggested, along with some interesting references to gender, religious background, and biorhythms. Ms. Williams' lesson soon turned into a discussion of what melting and freezing really mean, and it revealed how students develop those concepts over time.*

Ms. Williams reported that this short "experiment," with its charting of data and discussion, gave some contextual meaning to the standard solubility lab with its various molar solutions, crystals, Bunsen burners, round bottom flasks, and other technical m^t^rials and procedures. Temperature, surface area, friction, and pH, variables that are embedded in the Hershey Kiss activity and the solubility lab, are variables we encounter in numerous contexts. Thus, when these variables are first explored in relationship to known quantities, such as a Hershey Kiss, it is easier to understand how other elements, such as magnesium or calcium, become dissolved in water or hydrochloric acid.

This vignette shows staff development that is both continuous and on-going. Mr. Jackson's "new" job as Curriculum Associate had been in existence for several years as a means of helping other teachers integrate new learning into their classrooms by working with the teacher and that teacher's students, and he worked closely with teachers throughout the school year. He constantly met with teachers, both formally and informally, gathering feedback on the effectiveness of courses, seminar series, guest lectures, and other offerings provided by the district. He became a facilitator for collaboration; he formed study groups in each school and enlisted the support and expertise of colleagues in the schools to serve as presenters for each other. Teachers could examine their school and their own practice and their schools and work to formulate new and better learning opportunities for their students. One study group focused on constructivist principles and provided opportunities to model the constructivist perspective on learning. Mr. Jackson took on a role quite uncommon in most school districts, a role that supports teachers in pursuing their district's and their own staff development goals, and reveals the high priority the district gives to staff development.

Recommendation:

Staff development opportunities should include support and facilitation by knowledgeable, capable people whose role is focused primarily on teacher growth.

The following examples also highlight the recommendations stated in this chapter.

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Ms. Fithian's Implementation of *The Voyage of the Mimi*

Ms. Fithian teaches an environmental science course to seventh graders in a middle school. In the spring of 1983, Ms. Hamilton, the district's science coordinator, asked Ms. Fithian to participate in a summer curriculum project involving a new offering by Holt Publishing Company, ***The Voyage of the Mimi.*** *Ms. Hamilton had attended a preview presentation of the* ***Mimi*** *and was impressed with the film series on a whale-tracking expedition and the accompanying software. She believed that teacher input would be vital, however, in making any decisions about incorporating the* ***Mimi*** *series into the seventh grade science program. Ms. Hamilton had observed Ms. Fithian's science classes and perceived her to be well grounded in science concepts and the appropriate methods for teaching middle grade students. She believed that there was the potential for a nice match between this program and the official curriculum guide. (The school district's program of studies is developed with teacher suggestions.)*

That summer Ms. Fithian and two teachers from other schools were hired to view the ***Mimi*** *films, play the simulation games, and evaluate the series. The teachers were enthusiastic about the scientific content in the expeditions, the human relations and qualities highlighted in the episodes, and the appeal of the simulation games. They asked to pilot the program with their schools during the next school year.*

At this time the school district had set computer literacy as a general goal and established a division to coordinate the integration of computers and appropriate software into science classrooms. The science coordinator merged Ms. Fithian's interest in the ***Mimi*** *with her principal's interest in getting appropriate computer programs in the school. Thus, in the fall of 1983, Ms. Fithian and her colleagues piloted the* ***Mimi*** *program, including computer software, in their classrooms. Ms. Hamilton and her assistants visited classes in the pilot program regularly and discussed strategies and activities for the* ***Mimi*** *with Ms. Fithian. They received enthusiastic teacher reports and student evaluations. In May, the* ***Mimi*** *pilot teachers invited other seventh grade teachers and their building administrators to come to their school to view and discuss the* ***Mimi*** *program. Ms. Hamilton also made a presentation to the principal's association which prompted interest on the part of many principals in their school's participation in the* ***Mimi.***

Recommendation:

Staff development should not only focus on teacher needs and interests, but also attend to the goals of the school and district. Staff development should also involve administrators in key roles of advocate, supporter, and facilitator of change in classrooms.

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*During the following summer, Ms. Fithian was joined by four other teachers who volunteered for the program. They shared their pilot teaching experiences. This led to the development of new activities and the adaptation of others from the pilot program. The teachers developed a suggested timeline for using the **Mimi** program and guidelines for integrating the concepts of the new program with the core concepts of the seventh grade science course.*

*In the six years since the introduction of the **Mimi**, the science coordinator's office has supported staff development activities for Ms. Fithian and her peers. In 1985, Ms. Fithian and four seventh grade teachers participated in a week-long whale-tracking expedition, similar to that of the **Mimi**, from Gloucester, Massachusetts. All of the seventh grade science teachers were involved in marine research activities sponsored by the Chesapeake Bay Foundation.*

*As a result of the field trips for teachers, Ms. Fithian and her colleagues planned field trips for their students, including structured visits to the National Aquarium and the Virginia Institute of Marine Science, and the exploration of estuaries and freshwater environments in their area. One year Ms. Fithian's students participated in a Potomac River expedition aboard the schooner, the **Alexandria**. The following year they were involved, via satellite hook-up, with the research activities of the **Jason** in the Mediterranean Sea.*

Recommendation:

Staff development should take full advantage of local and regional resources to expand teachers' opportunities to explore, create, and grow.

Ms. Fithian has continued to meet with experienced seventh grade teachers to share experiences and collaborate on interdisciplinary activities, field trips, guest speakers, use of computer interfacing equipment, and adjustment of the program to meet the variety of students' needs and abilities.

*The **Mimi** teachers' work connected directly to their earlier district-sponsored staff development opportunities. Many of the teachers had participated in courses such as The Skillful Teacher, 4-MAT, and Teacher Expectations-Student Achievement (TESA), and they routinely share ways to apply the insights from these formal learning experiences to their classrooms. When the Skillful Teacher course, based on Jon Saphier's (1982) parameters of good teaching, was offered at her school, Ms. Fithian participated and worked regularly with seventh grade social studies teachers. They served as peer coaches for each other by identifying areas of concern, observing and collecting data, and then offering an analysis of the data. Ms. Fithian identified general areas of pedagogical concern, such as her implicitly and explicitly expressed expectations of students, and those specific to the **Mimi**, such as adaptation of curriculum to student ability and interest. She was able to assess her generic teaching strategies and develop activities related to the **Mimi**, such as the use of collaborative groups for navigational mapping activities.*

Recommendation:

Staff development opportunities should be integrated, building upon and complementing each other as the teacher's repertoire of effective approaches and strategies is enlarged.

*Ms. Fithian and other **Mimi** teachers also participated in the course, open to all teachers, offered by the district's office of Instructional Technology on word processing, data files, and creation of interfacing devices. These experiences have led to the development of materials for general use such as newsletters, record keeping and equipment ordering and for the **Mimi**, specifically, such as tests and activities using the computer as a laboratory through interfacing devices. At their general meetings, these teachers have shared experiences for creating tests and newsletters, record-keeping systems, computerized equipment ordering, and data storage for school science fairs.*

*Each fall Ms. Fithian meets with science teachers new to the seventh grade program, for a four-hour orientation session to the curriculum, including the **Voyage of the Mimi**. At that session she encourages the teachers to sign up for the college-credit course, taught by a team of seventh grade teachers, which provides hands-on experience with concepts and methods for the seventh grade course.*

Recommendation:

Staff development should provide teachers with opportunities to assume leadership and support roles with others; this not only broadens the perspective and rewards the individual, but it provides credible, exemplary role models to other teachers, especially those who are new and/or less experienced.

The incorporation of the *Voyage of the Mimi* into the seventh grade science program used all the recommendations set forth in this chapter. Here, Ms. Fithian's staff development experiences were continuous and on-going. Because there was gradual, supported implementation of the *Mimi*, Ms. Fithian had the opportunity to become knowledgeable, competent, and practiced in the scientific content and strategies appropriate for her students. She and the other teachers had time to reflect upon their experiences with students, interact with others, and build a strong commitment to the program. The staff development offered a variety of opportunities and incentives — new instructional and learning experiences, expertise in computer use, interaction with other teachers and experts, additional classroom resources, and salary credit — to address different teacher needs and account for the various stages of teacher growth and development. Consequently, the teachers became the strongest advocates for the *Mimi* program, which prompted the necessary support from building administrators. As a result of her involvement in the development of the *Mimi* curriculum, Ms. Fithian presented her students with activities which engaged their interest and focused them on meaningful interactions with their environment.

Principles of Good Staff Development for Middle Grade Science Teachers

These vignettes illustrate the different models, approaches, and strategies that schools and districts use to help teachers develop the knowledge, skills, and beliefs required for good middle grade science teaching. The approaches used emphasized a constructivist view of learning for teachers as well as students, one in which teachers were given sufficient and appropriate experiences to incorporate new ideas and materials into their own knowledge base and their teaching strategies. Teachers were helped to articulate their own conceptions of teaching and learning, giving them experiences to enhance or work on changing those conceptions, and providing opportunities to apply their new learnings in a variety of situations.

These vignettes also illustrate several general principles of staff development, ones which form the basis of our recommendations for the improvement of staff development for middle grade science teachers.

In summary, we recommend that staff development for middle grade science teachers model these principles, that it:

- is continuous and ongoing;
- provide opportunities for teachers to choose among staff development opportunities that match their interests, stage of development, and competence;
- provide opportunities for teachers to examine and reflect on their practice and their schools, and work together to formulate new and better learning opportunities for their students;
- model the constructivist perspective on learning;
- include support and facilitation by knowledgeable, capable people whose role is focused primarily on teacher growth;
- attend to the goals of the school and district as well as the needs and interests of teachers;
- involve administrators in key roles of advocate, supporter, and facilitator of change in classrooms;
- take full advantage of local and regional resources to expand teachers' opportunities to explore, create, and grow;
- integrate different kinds of opportunities to enlarge teachers' repertoires of effective approaches and strategies; and
- provide teachers with opportunities to assume leadership and support roles with others.


A COMPARISON

Chapter IV

Organizational Context and Support

The move toward excellent science education for middle grade youngsters is a major reform which will require a significant change in the institutional patterns and the knowledge and behaviors of the staff. New knowledge, skills, and beliefs for teachers and administrators; new organizational programs, norms, and structures for their schools; new curricula — this combination clearly constitutes a major reform effort. And yet, it is what we believe is necessary if we are to improve science education at the middle grade level.

The changes called for differ in two fundamental ways from those schools and teachers are used to. First, they differ in scale. It is not merely a matter of switching from one science text to another. Rather, the changes require a transformation both of the teaching process itself and the organizational context in which this broad-based, complex change can occur. Consequently, the changes differ in the requirement to address needs for both staff development and institutional development (Fullan, in press). One without the other will not meet the goal of good science education.

The changes we suggest are not what Cuban (1987) calls first order change, those that involve merely a change in strategies used to reach old goals. Such first order changes try to improve existing methods and structures of schooling without disturbing the basic organizing features. Rather, we are talking about second order change, a profound change in the purpose and the goals of the program or institution. Second order changes alter fundamentally the ways in which organizations are structured. As such, the issue to be considered by decision makers is whether the needed transition should be considered as a major reform in which many significant innovations and changes would take place rather quickly or whether it would be approached incrementally over a long period of time with a number of small-scale changes occurring rather slowly and sequentially. Although there are arguments and evidence that support both means of change, there is growing evidence that a major change, treated as a significant reform, has a greater chance of success than if it is treated as small incremental changes over time (Crandall et al., 1982; Fullan, 1982).

Throughout this chapter we will talk about the contextual and organizational support necessary to make changes in the school organization as well as personal changes in the behavior and knowledge of middle grade staff. Although there is considerable evidence in the school improvement literature to show that extensive school and district wide innovations can be implemented (Crandall et al., 1982), in many of the cases studied, the teachers involved were not required to make the kind of major shift in their behavior and goals necessary to accommodate significant change. Therefore, it is important to think simultaneously of institutional changes and the personal changes the staff will have to make to successfully implement the kind of middle level science program we propose. It might be appropriate to "think big and move toward it developmentally" (Fullan, personal communication).

We recognize the magnitude of the organizational and individual changes needed to transform middle grade science teaching. New science programs require a complex set of organizational shifts in schools and districts and a corresponding set of changes at the classroom level. In the previous chapter we discussed the importance of professional development opportunities for helping staff make the necessary changes. But staff development alone is not enough; institutions themselves must change if we hope to improve science education. In his review of studies of the National Science Foundation Summer Institutes from the 1960's, Bredderman (1983) illustrates the critical nature of the organizational support structures to the success of new science programs. He found that graduates of the summer institutes were often highly motivated teachers who typically were unable to sustain the newly learned approaches to science because of limited organizational and administrative support provided by the school and district. Of the graduates studied, only 20 percent were able to implement and sustain new science programs in their school settings.

What kind of organization promotes good science teaching? First, we believe that the school, not an individual classroom or department, must be the unit of change, and that the nature of the organization — its purpose, coherence, norms, leadership, and climate — determines whether meaningful change can occur. Then, we believe that support structures, resources, procedures and policies must exist to support change in science teaching at the classroom or department level. In this chapter, we talk about the organizational setting and support needed to implement and maintain good science teaching. Then, we suggest directions we need to go to further advance our thinking and action to improve science education at the middle level.

The Organizational Setting

The School as the Unit of Change for Improved Science Education

The changes expected of teachers discussed in Chapter 2 are so fundamental and significant that they cannot survive without the participation of the total school staff and its surrounding community. It is clear that it would be very difficult, if not impossible, for one department of a school, such as the science department, to take on a major reform of its goals, curriculum, strategies, and relationship to students without a parallel activity occurring in the entire school and without strong support at the district level. The necessary support and pressure would be difficult to provide to only one department.

One of the major goals of improved science teaching in the middle grades is to relate science to the other disciplines, usually through an organizational pattern where the science teacher is teamed with other teachers responsible for social studies, language arts, mathematics, and often, reading. This would be impossible without changing the structure and the approach of the entire school. Further, this school-based change must occur in tandem with institutional change at the district level if it is to become a lasting change.

Recommendation:

If reform is to occur in any department in the middle grades, the unit of change must shift to the entire school.

Our Center's elementary school report on teacher development (Loucks-Horsley et al., 1989), discussed several general characteristics of schools that are critical for meaningful change to occur and be sustained. These general characteristics are: (1) clear purposes and outcomes, (2) adequate, appropriate resources, including time, staff, and materials, (3) a robust conception of staff development, (4) norms of experimentation, risk taking, collegiality, and collaboration, (5) teacher involvement in decision-making, and (6) leadership and support.

In addition, there are more specific characteristics of schools that are designed to address the needs of middle grade youngsters. Hurd (1987) has summarized the list as follows:

1. Integration. Learning experiences are integrated into effective and wholesome pupil behavior as well as link the subjects in the curriculum.
2. Exploration. Schools lead pupils to discover and explore their own interests, abilities and skills, and provide opportunities to include cultural, social, civic, avocational and recreational interests as a basis for vocational decisions.
3. Guidance. Assistance is provided to enable students to make intelligent educational and vocational decisions and wholesome social and personal choices.
4. Differentiation. Opportunities are provided that accommodate pupils of different backgrounds, interests, abilities, and needs.
5. Socialization. Learning experiences are included that enable pupils as citizens to participate in and contribute to our democracy.
6. Articulation. Schools provide students with help in acquiring the backgrounds and skills that will help them succeed in later education and adult life (as summarized in Raizen et al., 1990).

This set of characteristics, while articulated by some as the "middle school concept," can also describe a more traditional elementary or junior high school setting that is open to complete change and to appropriately meet the educational needs of young adolescents.

Recommendation:

The school needs to have certain characteristics that 1) foster meaningful change and 2) address the special needs of middle grade learners.

Leadership for School Change and Improved Science Education

Almost two decades ago, Sarason (1971) pointed out that "change is more fundamental than it first appears" in that many aspects of classroom practice must also change when radical revision is made to some aspects of the classroom. His insights were drawn from the "new math" experience of the 1960's but remain true for second order reforms today. Consequently, school leaders must learn not just "how to bring about change," but more specifically how to facilitate the second order changes such as the kinds of science programs discussed in this report.

We have considerable knowledge about the process of implementation in schools and districts (Fullan, 1982; Huberman & Miles, 1984; Crandall et al., 1982) and the policy factors that influence such implementation (Odden & Marsh, 1988; Fuhrman et al., 1988; Anderson et al., 1987). But not as much is known about the process of implementing second order changes. Second order reforms are characterized by profound changes in almost every aspect of classroom practice, a paradigm shift for most teachers, and a restructured organization that allows for and supports such new classroom practices (see Murphy, 1988; Odden & Marsh, 1989).

What kinds of leadership traits are necessary to enable such profound changes to take place? Elements of strong organizational leadership have been documented in numerous studies of effective educational organizations and include: a clear and compelling vision, a proactive leadership style, strong communication networks, flexible strategies for achieving consistent long range values and goals, and reflection on practice and possible alternatives while maintaining action amid uncertainty [see Boyan (1988) for research on educational institutions and Bennis (1989) for a similar but more generalized perspective].

Recent work has identified elements of instructional leadership which Murphy (1988) has summarized as both direct and indirect instructional support, including:

1. Developing Mission and Goal
   - framing school goals
   - communicating school goals
2. Managing the Educational Production Function
   - promoting quality instruction
   - supervising and evaluating instruction
   - allocating and protecting instructional time
   - coordinating the curriculum
   - monitoring student progress
3. Promoting an Academic Learning Climate
   - establishing positive expectations
   - maintaining high visibility
   - providing incentives for teachers and students
   - promoting professional development

4. Developing a Supportive Work Environment
   - creating a safe and orderly learning environment
   - providing opportunities for meaningful student involvement
   - developing staff collaboration and cohesion
   - securing outside resources in support of school goals
   - forging links between the home and the school

Like teachers, building and district leaders need an understanding of the characteristics of good schools for young adolescents, such as those listed by Hurd (1987), above. This list must be augmented by the recent focus on curriculum that promotes depth in student thinking and problem-solving, especially the emphasis on "less is more," where students focus on essential knowledge which they explore in depth. This approach is illustrated in our Center's proposed curriculum framework (Bybee et al., 1990), which features attention to a small number of major concepts in the science and technology curriculum as well as an attempt to integrate and meaningfully link science and technology to other disciplines. In turn, this newly focused and integrated curriculum must serve two ends: be exciting to the student and focus on knowledge essential for future study and comprehension of the world.

Many district and building leaders lack a clear understanding of the nature and ingredients of good science teaching. While these leaders do not need the type of understanding that would allow them to teach such science programs in an advanced manner, they do need to understand enough to allow them to support, monitor, and integrate these programs within the overall curriculum. This level of understanding will take time and attention to develop in administrators; yet without it, most attempts to implement good science teaching will fail.

The surge of interest in teachers as professionals as well as the findings from the research on implementation points to the need for leadership teams at the district and school levels. Hall and Hord (1987) document the role which team members can play in a leadership team, and Odden and Marsh (1988) show how multiple teams are typically involved in implementing complex change. Collaborative leadership allows for the integration of top-down, power-oriented processes with bottom-up, expert-oriented change processes. Aspects of both processes are found to be necessary for implementing second order reforms. The collaborative leadership feature also allows for the integration of substantive expertise regarding good science curriculum and instruction with organizational leadership found to be critical in successful change efforts. In a similar way, the team must meaningfully link the macro world of the district (and often the state) with the micro world of the school and classroom. Schools and classrooms may no longer be the only viable unit of change; districts play a critical role that has only recently been analyzed (Fullan, 1985; Purkey, 1985; Odden & Marsh, 1989). More discussion of the nature of organizational support needed at the district level is provided later in this chapter and by Loucks-Horsley and her associates (1989) who discusses this issue in the context of good science teaching in elementary schools, but in a way that is easily generalized to middle grade situations.

School and district leaders require extensive training if they are to provide the organizational and administrative supports needed for middle grade science to

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flourish. Murphy and Hallinger (1987) synthesize a body of literature that documents how administrators (including those at the middle level) rarely serve as effective instructional leaders. Duke (1987) reports that middle level principals perceive they serve primarily managerial and administrative functions, rather than instructional leadership.

The problem is to provide leadership training that directly supports good science teaching and indirectly provides the organizational conditions where effective middle grade approaches can thrive. While comprehensive models for such training are difficult to find, recent advances provide considerable insight into important components. Such training must:

- include progressive views of organizational leadership;
- give specific attention to instructional leadership;
- even more directly address the administrative and organizational conditions needed to support good science teaching in a school designed for middle grade youngsters;
- help administrators and other leaders at the school and district level assimilate and apply critical factors needed to implement such important educational programs; and
- address the notion of shared leadership.

In addition to including new content, leadership development must use a new process for the training itself. Murphy and Hallinger (1987) describe the need for practice-relevant and credible trainers, adult learning techniques, multidimensional instructional strategies, and extensive attention to the transfer of training to the home site among other criteria for effective administrator training.

Recommendation:

We recommend training programs that help district and school leaders implement good science programs in schools designed to serve the needs of young adolescents. The training programs should integrate a) organizational leadership and general instructional leadership; b) directly address the administrative and organizational conditions needed to support good science teaching and the middle school concept; c) help administrators and other leaders at the school and district level assimilate and apply critical factors needed to implement such important educational programs; and d) support collaborative leadership and teacher professionalism at the district and school. Such training should incorporate adult learning strategies, multiple instructional modes, and extensive attention to the transfer of training to the home site.

Organizational Supports

When the organizational context or climate of the school is conducive to change, what structures or supports enable the desired change to actually occur at the classroom level? 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). The transition by both teachers and administrators to a school setting that addresses the needs of young adolescents is a major undertaking, both from the perspective of the individuals and the institution itself. Teachers need ample time and opportunity to learn and try out new ways of teaching science. They need to have access to curricular materials that support the new paradigm. Further, more centralized regional support — at the district or state level — adds substantial power to the reform effort. Here we address some of the ways these supports can be developed.

Staff Development Activities for Improved Science Education

Because the changes in science education we have recommended are so profound, it is imperative that professional training and support mechanisms are established outside the individual school. Rarely does a staff have enough expertise in its own members to make the required personal and institutional changes. One possible source of professional development could take the form of a series of regional academies focused on middle grade education.

Such academies could be established through joint efforts of state departments of education, universities, local school districts, and/or intermediate educational service agencies. They would be staffed by a variety of personnel, including master teachers, experienced administrators, university personnel, visiting consultants, and experts in student and program evaluation. Ideally these academies would be associated with or housed in a middle level school where new practices could be demonstrated and tested and where teachers and administrators could rotate into the staff for various periods of time for actual in-house training. Such a model is used for staff development of secondary school teachers in the Schenley High School in Pittsburgh.

Middle level academies would provide a wide range of services and experiences for both administrators and teachers, including:

1. Full or partial academic year on-the-job-training.
2. Intensive summer institutes focused on a variety of topics and issues, including training in teaching strategies and science content, and the development of curriculum and assessment approaches.
3. A variety of technical assistance services, where academy staff work closely with a school leadership team or an entire staff to plan, develop, and implement new structures and curricula, and
4. A depository of various teaching aids, curriculum packages, videos of classroom techniques, etc.

These would not be separate, discrete activities but would be coordinated to provide a series of professional growth experiences for staff from a school that might span a period of several years. As an example, an academy staff member could go to a school and present an orientation and awareness session before the school makes a decision to redesign itself. Once the decision is made, intensive summer institutes could be provided for much of the school staff at the academy, followed by an academic year experience for key members of the staff. Once the transition is underway at the school, technical assistance could be provided from the regional academy in the form of coaching, follow-up observations, evaluation support, etc.

One key role of a regional academy would be to provide the kinds of leadership development activities described in the previous section. Through a leadership development program, local school districts could develop adjunct academies as spinoffs of the regional academy that would free them from extensive dependence on the "mother" academy.

Recommendation:

Regional academies should be established to provide staff development and technical services to schools moving to redesign their settings to promote science education tailored to the needs of young adolescents.

Curriculum for Improved Science Education

An extensive amount of new curriculum will be required to support teachers and schools wanting to implement a model middle level program. *Turning Points*, the newest Carnegie Foundation report (1989), calls for a vast improvement in curriculum and instruction for the middle grades by

- teaching young adolescents to think critically,
- teaching young adolescents to develop healthy life-styles,
- teaching young adolescents to be active citizens,
- integrating subject matter across disciplines,
- teaching students to learn and test successfully.

In addition, the report suggests that "teachers should exercise creative control over how curricular goals are reached for their team, . . . choose instructional methods and materials for classroom use, identify and develop interdisciplinary curricular themes, schedule classes, select field experiences including youth services opportunities, and evaluate student performance in light of school wide objectives." (p. 55) With these expectations a totally new type of curriculum is called for.

Our Center's curriculum and instruction report (Bybee et al., 1990) further calls for the integration of science with technology; the teaching of ten major concepts (see p.12) through whatever topics are selected for study; and an instructional model that incorporates experiential learning and a constructivist perspective. In addition, our Center's assessment report (Raizen et al., 1990) calls for assessment approaches and tools that allow the teacher to constantly monitor and improve the quality of instruction, tracking student progress, including ones that are difficult to measure such as higher-order-thinking processes.

The curriculum we suggest, then, would have the following characteristics:

1. It is organized in interdisciplinary units where science and technology have been combined with social studies, mathematics, and health around a theme, problem, or issue. The ten major concepts are taught within these units.
2. Alternative instructional strategies are provided as often as possible in order to give both staff and students choices when studying a particular core topic.
3. It includes examples of actual student responses, collected while the units were being tested. This allows teachers to understand how typical middle grade students have responded to the curriculum, giving them a glimpse into the developmental level of students, and helping them better understand the constructivist approach used in developing the curriculum.
4. Each unit contains a variety of techniques to measure student outcomes, particularly those concepts and strategies that call for higher level thinking and problem-solving skills.
5. Units are written in a way that requires some level of local adaptation. This provides alternative routes through the curriculum or a variety of activities that can be assembled in several sequences. The curriculum is available in loose-leaf format, short modules, or even in desktop publishing format so that local schools and teacher committees are both encouraged and supported to do their own adaptation and publication.

Recommendation:

Curriculum designed according to the above specifications should be developed on a continuing basis by federal, state, and locally funded groups.

An outgrowth of this recommendation is that such materials are made universally available through a clearinghouse or central depository. In the past, curriculum appearing in module format and having this type of flexibility has not been profitable for commercial publishers.[2] This leads us to another major recommendation concerning curriculum.

Recommendation:

Curriculum developed for middle grade science (and other subjects as well) should be published and made available through sources other than the "for-profit" publishing companies.

[2] During the 1970's the BSCS developed a major set of materials for the middle level entitled Human Sciences that met virtually every one of the above requirements. The major publishing companies of the country rejected the opportunity to publish the materials which were finally published on a small scale by a new, small science equipment and chemical company. The materials were never profitable and were removed from the market a few months after publication. Other examples of modular type materials that did not succeed on the open market at the middle level include the ISCS materials. At the high school level several programs were published in modular format, including Interdisciplinary Activities in Chemistry (IAC), Action Chemistry, Individualized Science Interdisciplinary Study (ISIS), and others. None of these could be sustained on the open, for-profit market

State and District Policies for Improved Science Education

Many of the most powerful levers influencing the viability and effectiveness of good science reside in state and district policies regarding assessment, curriculum, instruction, teaching and the licensing of teachers, and other related areas. States and districts also have policies and considerable influence on funding and the use of resources, as well as regulations that constrain and direct almost every aspect of life in schools.

The Center's report for elementary school science (Loucks-Horsley et al., 1989) recommended that states and/or districts develop comprehensive structures and support systems that have, at a minimum, the following elements: (1) shared purposes and goals for good science programs, (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, we recommended that districts should have systems for (6) curriculum development and (7) materials support. Such support structures are typically even more in need for the middle grades because the concept of a setting designed for young adolescents is more recent and more divergent from previous practice, and middle level programs lack the same attention and constituent support enjoyed by elementary or even high school programs.

California provides an example of how state support for science education can be coordinated. A state curriculum framework is prepared every seven years by a committee that includes teachers, district leaders, state leaders, and university-based scholars. The framework includes statewide goals for science education as well as core knowledge and general instructional strategies. In preparing the guide, the committee draws heavily on national reports, professional association proposals, and synthesized research. At the same time, since the committee includes progressive practitioners, the framework has two other strengths: a) being "user friendly" and b) support by a statewide network of committed practitioners.

Another state committee then adopts a range of instructional materials that fit with the view of science education found in the framework. California has been proactive in compelling textbook publishers to develop new types of materials that fit, at least approximately, their curricular goals. Districts then review their science curriculum in view of the state framework and select instructional materials that fit both local preferences and statewide goals for good science; research has found that the most successful districts transform the general state goals into a crisp district vision and direction for science; the process is dynamic and proactive about good science, and districts feel supported in their efforts by the state goals and textbook adoption process (Marsh & Odden, in press).

Equally as important are the multiple ways that the state facilitates the local implementation process. Many districts send district and school leaders to regional conferences regarding implementation and lead teachers to summer institutes where science curriculum and instruction are intensively explored. Teachers helping other teachers to improve their instruction is a key feature of the summer institutes.

Districts also "deploy" state-funded mentor teachers from their districts to help other teachers implement the new science approaches. In a similar fashion, county offices of education and organizations such as the Lawrence Hall of Science at UC Berkeley develop on- going networks of leaders in districts. These networks link staff development with materials and exemplary program modules to enhance local implementation. The state- funded School Improvement Program provides developmental funding and planning assistance to local sites as well as a sequenced self-study/external program review process that lets middle-level schools examine how they look vis a vis the state curriculum frameworks and the state task force report (entitled *Caught in the Middle*), which synthesizes essential features of a comprehensive middle-level school.

Finally, the state assessment program promotes and monitors good science education. At the middle grade level, eighth grade students are assessed using a matrix-sampled test that emphasizes good science education.

Recommendation:

State and district policies should be developed to support good science and technology education. Organizations such as the Educational Commission of the States and the relevant national science educational associations should develop a technical assistance strategy that helps states, in collaboration with districts within those states, improve the policy context within which good science programs can flourish.

Future Directions for Improving Science Education

Additional Documentation and Research

Our recommendations for changes in the organizational contexts and support for middle grade science are based on general school improvement research and reports of exemplary practice. Clearly, there is a need to deepen our understanding of the process of implementing major reforms such as those we recommend for the middle grades and the lasting effects of these reforms on school structure, classroom patterns, and student learning. Several types of research are needed. First, action research is needed to help policymakers and practitioners understand and facilitate more powerful implementation processes required to accomplish good science teaching in the middle grades. The studies should document and analyze the transition to these new forms of programs under different policy contexts, such as in states with a tradition of strong local control or in other states where state leadership has been progressive and active. The audience for these studies would be local and state science leaders.

At the same time, more controlled studies of the feasibility of large scale implementation of these bold reforms are needed. For these studies, the audience would be policy makers and scholars concerned with clarifying what implementation factors are critical, what program configurations are likely, what impact various patterns of budget and policy levers are having, and what outcomes are likely. These feasibility studies are needed for a more summative review of the directions these reforms are taking and how to maximize their benefits.

Finally, while considerable research is available about the impact of good science teaching at the elementary level, there is much less research about the curriculum content, instructional processes, and learning patterns characteristic of good science programs at the middle grade level. With the recent surge of work in cognitive science linked to the various academic disciplines, a rich potential for research on learning in this context exists. This research is especially needed given the dramatic shift in pupil demographics and the need to link science education to our economic viability in a swiftly changing world.

Recommendation:

Further study of good science education in middle grades is needed. We recommend three types of studies: 1) Action research to document and analyze the transition to these new forms of programs under different policy contexts such as in states with a tradition of strong district leadership or in other states where state leadership has been progressive and active; 2) more controlled studies of the feasibility of large scale implementation of these bold reforms, clarifying what implementation factors are critical, what program configurations are likely; 3) research about the curriculum content, instructional processes and learning patterns characteristic of good middle grade science programs, especially on cognitive science linked to the various academic disciplines.

Review of the Relationships Among Academic Disciplines

A need exists to examine the relationship of science curriculum and instruction to the curriculum and instruction found in other parts of the school. At the local level, this exploration is critically important. Currently, students in our secondary schools typically experience a fragmented curriculum, where each successive class throughout the day pushes the student to master often trivial and disconnected information about a host of disjointed subjects. It is no accident that a departmentalized curriculum leads to a compartmentalized mind for the student. Sizer (1983), Goodlad (1984), and Boyer (1984) have described the numbing effect of this approach to schooling; it leads to student docility and disengagement, with disastrous consequences for the student, the life of the school, and the future of the nation.

For schools to address the needs of young adolescents, the curriculum must, instead, be organized around an integrated core that links the academic disciplines and focuses on essential knowledge. A clearer view of this integrated curriculum would not only help students, but also teachers and administrators who struggle to implement reforms in many areas of the curriculum while under severe budget and staffing constraints.

Scholars and practitioners have continually wrestled with the issue of the desired and conceptual relationship among the various academic disciplines. Dewey proposed a "continuity of experience" perspective that emphasized what we now call the social construction of knowledge, the need to integrate and make meaningful such knowledge, and the ways that various academic disciplines could serve this quest for integrated and personalized knowledge. Historically, however, the press for greater focus on the academic disciplines themselves was one major reason for the isolated, fragmented curriculum as previously described.

Two recent national trends offer considerable promise for the conceptual integration of curriculum and instruction across disciplines, and in powerful new and useful ways. We believe that these trends offer the possibility for increased viability and effectiveness of the science education reforms discussed in this report. The first trend is the similar focus on problem solving, conceptual thinking, and the creation of meaning found in many of the major academic disciplines of secondary schools. Similar to the science teaching paradigm shift is the shift that has taken place in mathematics, English/language arts, second language learning, and the social sciences. In each case, the relevant major national professional organizations have synthesized research and position papers that emphasize what to us seems to be a similar direction.

The second trend is the direction of research on effective instruction. Over the last decade, a growing disenchantment with generic "effective instructional strategies" and thinking skills taught in isolation led the way to interest in instruction related uniquely to each academic discipline. In the last several years, however, the shift has been toward seeing the underlying similarity of instruction around the new paradigms. For example, at the 1989 annual meeting of the American Educational Research Association, Brophy synthesized research about instruction related separately to various disciplines into a new view of instruction that emphasizes the underlying similarities in these new approaches to instruction.

In short, the time is ripe for a new national focus on the conceptual similarities among the disciplines. Such a focus would help researchers and policymakers, but equally as important, it would provide much needed guidance to middle level school leaders who struggle to reach and engage students, fulfill the promise of an integrated curriculum as a foundation of middle grade reform, and survive the intense demands for reform and change in many areas of schooling.

Recommendation:

There is a need to examine the relationship of good science and other academic disciplines in the middle grades. We recommend that a national review and synthesis of the common elements in the various academic disciplines be undertaken so as to help middle level programs fulfill their desire for an integrated core curriculum while maintaining the vitality of good science approaches.

Chapter V

Preparing Teachers for the Middle Grades

Creating opportunities for inservice teachers to learn what they need to know to teach science well to middle grade youngsters would not be so critical if new teachers came to their positions at the middle level with the knowledge, skills, and beliefs they needed. Unfortunately, they do not. So at the same time that attention is necessary to staff development and working conditions for current teachers, teacher preparation needs attention as well.

In 1985, Fullan noted that preservice teacher education in general was "not in as good a shape" as inservice education. It would be difficult to argue that much has changed since then. The same unrealistic expectations and design deficiencies Fullan noted are true now. He argued that "whether one or seven years long, preservice programs can never be intensive enough, long enough, or real enough to result in the kind of product that preservice programs purport to pursue if one were to believe their objectives" (1985:3).

The Holmes Group (1986) further faults current preservice teacher education. They argue that most university teaching does not model exemplary teaching practice, nor do instructors understand the pedagogy of the material they teach. Academic areas are generally presented by fragmented courses so that students cannot easily gain a sense of the intellectual structure or boundaries of their disciplines.

Design deficiencies persist in the overall schema of teacher preparation as well. The responsibility for preservice education lies with an organization (of higher education) that is removed from the organization of employment (the schools); the reward system in higher education does not value the kind of development, teaching, and collaboration necessary to educate teachers well; and the course structure and scheduling constraints of higher education organizations do not support the intensively field-based and personalized programs needed for good teacher preparation.

The preparation of middle grade teachers has these problems in addition to no real identity of its own. By and large, teachers graduate from programs with either an elementary or secondary emphasis. In their 1987 survey, McEwin and Alexander learned that fewer than one-third of teacher education institutions in the country had programs for middle level teachers. The creation of teacher preparation programs for middle grade teachers lags far behind the rapid increase in the number of middle level schools in the U.S. (Alexander & McEwin, 1988). Only a few states have established middle level certification, and specialized middle level teacher preparation programs are concentrated in those areas (NMSA, 1986).

In viewing the future of teacher preparation programs in general, those for middle grade teachers in particular, and those for middle grade science teachers even more specifically, it seems best to backup and view them as part of a career-long continuum of teacher education (Fullan, 1985; Hall et al., 1984). This addresses the problem of unrealistic expectations noted by Fullan and is one of the reasons we have chosen to address preservice preparation after, rather than before, staff development. In earlier chapters we discussed the idea that learning is an individual matter, that it requires a wide range of experiences, structured exploration, and construction of meaning for new ideas. Given the many things middle grade teachers need to learn — characteristics of young adolescents and good middle level schools, pedagogy, content, etc. — it makes sense that teachers could and should learn what they need to know at different times in their careers, including before their careers even begin. Viewing teacher education as a continuum that begins before certification and lasts until retirement allows for more flexibility in programming and forces more of the critical collaboration between higher education and schools, as they share responsibility for teachers in every stage of their development. This last begins to address many of the design deficiencies noted by Fullan (1985).

The Holmes Group (1986), in viewing this educational continuum, recommends several stages of licensure and corresponding training and responsibilities to recognize teacher development as an ongoing process, beginning with a temporary certificate for those teachers with only a bachelor's degree.

In this chapter we begin by describing how middle grade teachers are currently prepared. We then discuss and make recommendations for an ideal middle level teacher preparation program, one that would not result in a "ready made teacher," but a teacher with a sufficient amount of the knowledge, skills, and attitudes discussed earlier to serve responsibly on a teaching team, while continuing to learn throughout his or her career. We include a discussion of an induction program that would intensify and structure learning for the beginning teacher.

The Present Situation

As noted above, most middle school teachers graduate from programs with either an elementary or secondary school emphasis. Elementary teacher education programs are typically very child-oriented, but they lack appropriate course work in science to create teachers who are competent and confident in that field. Teachers often take only one or two science courses in their program, typically a biology sequence (Weiss, 1987), with very few having any work in earth or physical sciences. The science courses they take rarely focus on societal issues, nor do they mirror the nature of science. Most elementary education graduates leave the college or university afraid of science and convinced that it is not a basic for schooling.

Elementary education majors typically have a broad general education background (often constituting one-third to one-half of their total collegiate coursework) in the humanities, social sciences, and in some cases mathematics and science. However, almost all graduates lack depth in any one field. Thus, they are experts in no content area (Loucks-Horsley et al., 1989). This lack of depth becomes a problem at the middle level where teachers are supposed to be "experts" in one or more subject area.

Secondary preparation programs, on the other hand, prepare teachers who are content- oriented and not well prepared in pedagogy, especially not the pedagogy most appropriate to young adolescents. Even with the content orientation, teachers often know only facts and definitions, lacking many of the deeper understandings even in their major discipline. They are rarely content experts. They do not view science as a way of knowing, rather they see it as a body of knowledge to be mastered. In many cases depth is attained at the expense of breadth, their major being the only science discipline they know. Graduates often do not understand how the sciences relate to each other, how science relates to other areas like the social sciences and humanities, nor how science and society influence each other.

Foundation courses taken by both elementary and secondary education students leave them unprepared for the emotional and behavioral extremes of the young adolescent. While most take a course in learning and development, this often does not help them work with the middle grade student. Neither level program helps its graduates understand how a middle level program needs to be structured to better meet the needs of the turbulent years of early adolescence.

Elementary education graduates are well prepared to take on some of the non-science roles required of all middle grade teachers, especially the teaching of reading and writing. However, this sometimes has adverse effects, since they are apt to over-emphasize this role when they begin teaching, feeling most comfortable with it. Secondary teachers typically ignore the problems of reading and writing, since they neither understand their importance nor how to teach them. Neither elementary nor secondary teachers easily assume the role of middle level teacher as advisor and counselor, since this role is almost always ignored in their preparation programs.

In terms of pedagogy, elementary education majors tend to be less oriented toward lecture and more willing to involve students in active, nontraditional activities. However, not all such activities promote student thinking, since many fall into the category of low level busy work. Secondary teachers tend to lecture as the major, if not sole, instructional activity. They neither know about nor value the need for active learning, for using a constructivist perspective.

While more and more elementary and secondary preparation programs have fairly strong field components, there are very few field settings where teachers in training can see and work with good middle grade science teachers in exemplary middle schools. Furthermore, field experiences are more often than not disconnected from science courses and courses in pedagogy, with the connections left to the students, who have insufficient background to make them.

This rather gloomy picture is fairly widespread, yet there are many ways of improving middle grade teacher preparation and several institutions where exemplary practice is occurring. These are discussed in the next section.

Good Practice in Middle Level Science Teacher Preparation

Rethinking preparation programs for middle grade teachers provides a unique opportunity to do more than "tune up" existing elementary programs or "tune down" existing secondary programs. Yet it is important not to exclude these possibilities, especially if a given program has a component that is specifically geared to preparing teachers for middle grade youngsters, and does so well.

Teacher education candidates need extensive experience in an academic field and some knowledge of others to integrate content and pedagogy. This cannot happen unless their education is restructured, with a program designed to blend content and pedagogy — two areas that are typically separated into content courses and education courses. If, however, as Shulman (1986) persuasively argues, it is a teacher's "pedagogical content knowledge" that makes a difference in student learning, new programs need to incorporate that knowledge and work at better integration.

The National Middle School Association (1986) cites the following components of middle level teacher preparation programs as essential:

- thorough study of the nature and needs of young adolescents,
- middle-level curriculum and instruction,
- a broad academic background, including concentrations in at least two academic areas at the undergraduate level,
- specialized methods and reading courses, and
- early and continuing field experiences in good middle level schools.

Preparation programs should also begin to develop their students as reflective practitioners (Schon, 1983; Cruickshank, 1987). Even students in their first year of preparation can begin to reflect on teaching, perhaps by examining the teaching they see in courses in their major field, as they begin to study how teaching and learning are related. Opportunities for such reflection would then continue to grow and change in emphasis as students reflect on their observations of middle grade teaching and then on their own teaching.

The Holmes Group (1986) believes a program of professional study for teacher preparation should include:

- the study of teaching and schooling as an academic field with its own integrity,
- knowledge of the pedagogy of the subject matter,
- knowledge of the skills and kinds of understandings implicit in classroom teaching,
- dispositions, values, and ethical responsibilities that distinguish teaching from other professions, and
- integration of all aspects of professional studies into the clinical experience where formal knowledge must be used as a guide to practical action.

In addition, as we argued earlier relative to staff development programs, preparation programs should not only teach, but should demonstrate the constructivist perspective. Just as we want prospective science teachers to see that science is both process and product — that it is knowledge developed over time and a way of asking questions and seeking new knowledge — so, too, do we want prospective teachers to know that education is both a body of knowledge about teaching and learning as well as the disciplined study of how that knowledge emerges. A program should address such questions as:

- what is candidates' prior knowledge of teaching and learning?
- what are their alternative concepts about teaching and learning?
- what kind of experiences can encourage them to wrestle with old and new ideas about teaching and learning?

Construction of new notions of teaching and learning takes time, and argues for a much more intense, highly integrated preparation program than prospective teachers typically have.

These general themes — integration of content and pedagogy, reflection on practice, and a constructivist perspective — should characterize middle grade teacher preparation programs. In addition, the following components are needed: general education, science content, foundations of middle level education, preparation for non-science teaching roles, pedagogy, and field experiences.

General Education

All teacher education graduates need a broad background in the humanities, social sciences, sciences, mathematics, and the fine arts. As the Holmes Group (1986:63) points out, "Of all professions, teaching should be grounded on a strong core of knowledge because teaching is about the development and transmission of knowledge." Such a broad base of knowledge is important for middle grade teachers, who must work with teachers of other disciplines and understand enough about each to carefully design interdisciplinary units of instruction. Modeling broad knowledge and interests helps students see the connections across the content areas they study.

Yager and Pennick (1990) suggest that if prospective science teachers have some background in the applied science fields (engineering, nutrition, agriculture, conservation) they will better be able to apply science, rather than just study it. Knowledge of social studies is important to place science in a personal, societal, and historical context. These authors further support a science/technology/society approach and recommend experience in working with a local or community issue related to science and technology. Science can then be meaningful and useful.

Recommendation

At least two years of an undergraduate degree program for prospective middle grade teachers should be focused on acquiring a broad background in the humanities, social science, mathematics, and the fine arts.

Science Content

Teacher education candidates need depth in a field or fields of science, for without depth, they will not be able to acquire pedagogical content knowledge. Because middle grade teachers are typically called upon to teach either life, earth, or physical science, they also need basic understanding of the major concepts in each broad field.

Middle level teacher education provides two options for prospective teachers: specialization in one subject area (for example, science) and specialization in two subject areas (for example, science and math, or science and social studies). For the first, NSTA (1987) guidelines suggest 45 semester hours of science, with 8 to 10 hours in each of three major areas — life, physical, and earth — and electives making up the rest. An alternative for specialization in one subject area is to major in one science field (that is, take 30 hours), with the remaining 15 hours in other science fields.

Recommendation:

For those pursuing a single subject specialization in science, we recommend a major in life, earth, or physical science (usually about 30 semester hours).

Two subject-area specialization is most often recommended by middle level educators (Alexander & McEwin, 1988). For programs of this nature, NSTA (1987) recommends 24 hours in science spread equally over life, earth, and physical sciences. An equal number of hours must be attained in a second subject matter, such as math or social sciences.

More important than how much science (i.e., traditional semester hours) is taken is the nature of the science courses. Science courses currently offered in colleges and universities rarely organize their content in optimal ways for teachers to use it, nor does the way they are taught model good pedagogy (Yager & Pennick, 1990). Instead, they organize their discipline around a set of facts and principles, ignoring such important questions as: 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 is built? (Anderson & Smith, 1987) As Arons (1983:94) points out:

> to develop a genuine understanding of concepts and theories, the college student . . . 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.

Few current college level science courses do so. In addition, in most science courses, students are rarely helped to identify common ideas across science disciplines, nor are the courses presented in such a way that common themes cut across the various departments or are presented by all science areas (Blosser, 1986).

As noted in our Center's elementary report on teacher development (Loucks-Horsley et al., 1989), the best science courses:

- 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,
- are interdisciplinary in that they relate their particular field to related fields (for example, 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:

- focus 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 (for example, 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 database and skills are developed.

Recommendation:

Scientists and science educators should work together to create better, more meaningful science courses for all students in higher education, especially at the introductory level. To support this happening, colleges and universities should seek means to better reward faculty for excellence in teaching and curriculum development.

Several current middle grade teacher preparation programs, funded by the National Science Foundation, are addressing the issue of more meaningful content courses. At Northern Arizona University, while participating in regular science courses, prospective teachers attend special laboratories that integrate concepts in two science disciplines, for example, chemistry and botany. Labs are developed by teams of four: two science professors representing the disciplines being integrated, a mathematician, and a science educator. Prospective teachers are also introduced to middle-level science activities developed by inservice teachers that are based on the concepts illustrated in the labs.

At the University of Georgia, students in the middle school program are required to select two fields of specialization to broaden their perspective and demonstrate the interrelation of disciplines. They take courses in content and methodology for the specialization areas; the two-year (junior and senior) professional training program emphasizes the interrelation of the content fields and integration of the subject specializations.

Lesley College's middle school teacher preparation program features an interdisciplinary liberal arts major in math and science. All math and science courses are taught so that the teaching models what should happen in a middle-level classroom; they emphasize active learning. The program includes three interdisciplinary courses that elaborate the interrelationships between mathematics, science, society, and the teaching profession. The emphasis is on methods of inquiry, criteria for truth in different disciplines, and an understanding of the nature and limits of knowledge. The interdisciplinary component culminates with a student research project in the natural sciences using scientific and behavioral science methods.

The State University of New York at Potsdam has developed an interdisciplinary science major for preparation of middle school science and mathematics teachers. The curriculum includes four sequential interdisciplinary science courses (two chemistry/physics courses and two biology/geology courses for a total of 24 semester hours) at the freshman and sophomore levels and a set of science electives (12 semester hours) at the junior year level. As seniors, students complete liberal arts and professional education program requirements. The nature of the courses provides a model of teaching interdisciplinary science. Each course consists of three one-hour lectures and two three-hour labs per week, and the lab activities emphasize "hands on" learning. The entire program focuses on modeling good instruction as well as teaching science content.

Hampton University's focus has been the relationship between science, technology, and society in its model middle school teacher preparation program. They offer experimental courses in which science concepts are developed around socially relevant issues, and in which the traditional distinctions between lecture and laboratory do not exist. Classes are student-centered and activity-oriented. The 36-hour science program includes biology, physical science, chemistry, physics, earth science, environmental science, zoology or botany, advanced zoology or botany, a second semester of chemistry or physics, and an elective from geology or marine science. In their sophomore year, students begin significant classroom observations and seminars and take a one-semester student internship in their senior year (Doody & Robinson, 1988).

Boston University's Project PROMISE (Program in Middle School Science Education) provides a two-year sequence of courses for science majors including an interdisciplinary course in "Cosmic Evolution." This university also has courses on the materials of science: Design and Construction of Science Equipment and Selecting, Curating, and Use of Biological Materials. Special instructional materials have been developed to accompany these courses.

The DIRECT Middle School Science and Mathematics Project at Oklahoma State University is a cooperative venture between the College of Arts and Sciences and the College of Education. Students major in a science content area and, in their senior year, take "capstone" courses in biology, physical science, and earth science which integrate their learning experiences. These courses model the kind of teaching appropriate at the middle level and are taken concurrently with science methods courses.

Foundations of Middle Level Education

Teaching science is a complex and not easily mastered craft, which is further complicated at the middle level by the special needs of the young adolescent. At one moment moody and brooding, and the next cheery and playful; emotional outbursts which flare, then disappear within minutes; demanding to be treated in an adult fashion one morning, and playing with childhood toys an hour later; a boy 4'10" and a girl 5'10" working as lab partners; all these describe the young adolescent. About the most reliable constant is their variability and unpredictability, which makes teaching them a demanding challenge.

Presently, neither elementary nor secondary teacher education programs prepare prospective teachers to deal with these complicated behavior patterns. As a consequence, after a few years, many teachers look for a "promotion" to the high school or yearn for a class of younger children who are "nice" (read "human").

The Carnegie Forum (1986:71) includes in its recommendations an "understanding of children's growth and development and of their different needs and lea.ning styles."

A basic grounding in the nature of the middle grade student and the kind of school needed to support his or her learning and development is a necessity for success in middle grade science teaching. Such a grounding implies that prospective teachers understand:

- the intellectual, physical, social, and emotional nature of the young adolescent,
- basic theories of learning which underlie methods of teaching the young adolescent,
- the nature of schooling in general and of the middle school concept in particular,
- the importance of the community and culture as they relate to schooling.

Recommendation:

Middle grade teacher education programs should include:

- **basic theory of early adolescent development and how it affects the learning and socialization processes in schools, learning theory as it relates to the early adolescent,**
- **work with the nature of schooling, the middle grade school, and the society, and how these relate to teaching the middle level child,**
- **early and continued experience with young adolescents both in and out of traditional school settings, as an adjunct to courses on development, learning, and middle school organization and philosophy.**

Middle grades teacher education programs with early adolescent development as a major theme are not unknown (Alexander & McEwin, 1988). The University of North Carolina at Charlotte incorporates a course on the physical, social, cognitive, and affective developmental factors that influence growth and achievement of 1? to 14 year-old students. Their program also includes a course on Middle Grades

University of Vermont professor, Chris Stevenson, gives potential and practicing middle grades teachers insight into the developmental changes that children age 10 to 14 undergo. He has videotapes of a small group of middle grade students in November of their 5th, 6th, 7th, and 8th grade years. In the videos, he works with each student individually, beginning by asking the student to describe him or herself. Participants in the middle grades course see adolescence unfolding before their eyes. The physical characteristics of the students change dramatically from year to year. Participants get an idea of the social world of each student as they discuss their involvement with best friends and other peers through classes, sports, and after- school activities. Emotional and moral development are clearly shown as the students describe their attitudes and feelings towards animals, hunting, war, and siblings. The students identify themselves with what they like to do and can do well: fix mechanical things, ride horses, ride mini-bikes, do karate, write poetry, play sports. Their interest in such areas as nature and collections is often brought out in their discussions. This kind of information provides insight into concept development and learning styles of students of this age, particularly for their need for active learning opportunities.

This sequence of videotapes is an example of a powerful tool for instruction that helps illustrate and develop understanding of young adolescents.

Education that provides an overview of education in the middle grades and emphasizes foundations, organizational patterns, instructional programs, and management techniques relevant to the middle grades.

The University of Georgia's program focuses first on the nature of the middle grade learner, the concept of the middle school as a separate institution, and the role of the teacher in this setting. Coursework includes an introduction to the middle grade school and adolescent psychology (with emphasis on early adolescence) and uses this as a theme throughout pedagogical coursework. There are courses on Teaching in the Middle School and Middle School Curriculum and extensive observation at the middle grade level, leading up to the senior year student teaching experience.

At the University of Northern Colorado, students working toward middle grades certification (in Colorado, this qualifies a teacher to teach grades 5 to 9 in a middle or junior high school) take a psychology course in adolescent development as well as Orientation to Middle School, which explores needs and characteristics of young adolescents and curriculum components and instructional approaches appropriate for this level student.

Oklahoma State University's program includes courses in adolescent psychology, middle school methods and learning theory for adolescents as well as clinical experience at the middle level leading up to the student teaching semester in the senior year.

At Lesley College, students take courses in middle school philosophy, developmental psychology, meeting individual needs, and inquiry learning, all focusing on the middle grade learner.

Preparation for Non-Science Teaching Roles

Prospective teachers need to understand the multiple roles played by the middle level teacher, and have some initial experiences that help them fit those roles. Because middle grade schools require so much coordination and cooperation — among teachers and with administrators, parents, and students — prospective teachers need direct training in a variety of interpersonal skills. These include active listening, group dynamics, conflict resolution, collaboration, and preventative maintenance behaviors.

Teachers also play important management roles, particularly in managing active learning environments with multiple instructional and non-instructional demands. Skills in task, time, and people management come in handy in a middle grade classroom. The report of the Superintendent's Middle Grade Task Force (1987) in California emphasizes the need for teachers to develop good human skills, including those that relate to group dynamics, principles of motivation, the sociology of change, systems of reward and affirmation, group cohesion, collaborative planning, the dynamics of innovation, multicultural and linguistic influences, conflict resolution, and peer group relationships.

Middle grade teachers play leadership roles with their students as well as with their peers, so prospective teachers can benefit from leadership skill development. They also serve as role models, advisors, mentors, and counselors, necessitating some knowledge of the principles of guidance.

Finally, all middle grade teachers need to be able to teach communication skills, especially reading and writing. Those preparing to be science teachers need some grounding in language development and strategies for teaching it.

Recommendation:

Middle grade teacher preparation programs need to include opportunities for prospective teachers to develop knowledge and skills to assist them in their roles as managers, leaders, role models, advisors, language teachers, and as collaborators with a wide variety of people.

Pedagogy

> Obviously some work in basic science is important — but perhaps not so important as it has been in preparing to teach science. More important than information a teacher acquires about science is a teacher knowing how to inquire, how to find answers, how to use material and human resources, and how to model these in a science classroom. (Yager & Pennick, 1990:663)

Teaching in the middle grades science classroom takes more than knowledge of science and an understanding of and ability to deal with the young adolescent. Being able to guide learners to a better understanding of scientific principles also demands a thorough knowledge of pedagogical principles that promote science learning, i.e., what Shulman (1986) calls pedagogical content knowledge. Without a repertoire of teaching strategies and knowledge of up-to-date curriculum and teaching aids, even the most well intentioned teacher often turns to lecture and discussion as the primary, if not sole, mode of teaching.

The California Superintendent's Middle Grade Task Force (1987) recommends several pedagogical emphases for teacher preparation programs:

- instructional strategies involving active learning
- special attention to middle grade core curriculum
- teacher proficiency in cooperative learning techniques
- teacher competence to address individual learning difficulties
- engagement of higher order cognitive skills
- teaching reading and writing in content areas

Coursework in pedagogy is an often criticized and many times condemned component of teacher education programs. Yet, there is an acknowledged need for prospective teachers to develop various pedagogical concepts and skills. Most important is the need to prepare middle-level teachers in strategies dictated by the nature of the young adolescent (Rouche & Baker, 1986).

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There are many such strategies. Because of students' relatively short attention span, a class period of instruction with several changes of activity keeps students more interested and attentive. Lessons with a high degree of activity appeal to young adolescents' need for physical involvement and movement. Tasks focusing on important societal issues in science appeal to the emerging sense of social justice often exhibited by 10 to 14 year-olds. Learning disguised as fun is eagerly devoured. Challenges to analyze and think through problems with appropriate teacher guidance appeal to their developing ability to think abstractly. This is not to suggest that activity and variation for their own sakes are useful; rather, learning opportunities that are carefully crafted to engage the interest of the students are more likely to engage them intellectually as well.

Some of the teaching strategies useful to implement such lessons are generic in nature. Prospective teachers must be taught to be excellent questioners, to become disciples of a modern Socratic method. An expert in questioning is able to draw a student into a scientific dialogue, enabling the questioner to analyze the student's depth of understanding and to use this as a basis for stimulating further thinking and analysis. Responding to questions forces students to examine their own knowledge and its relationship to newly gained insights, and to synthesize new insights.

Cooperative learning (a teaching strategy which views students as dynamic learners who learn with their peers in groups) is an example of an effective generic strategy that needs to be a prominent part of teacher education programs. A science activity based on cooperative learning fosters shared responsibility for learning, creative thinking, shared leadership, trust building, conflict management, as well as the skills of communication and problem solving.

Even lecture-discussion, if practiced properly, can be a useful strategy with middle grades students and thus needs to be part of the pedagogical repertoire of the preservice teacher. Using this strategy successfully with middle grades youngsters demands that teachers present information in short, easily digestible bits (no more than 10 to 15 minutes at a time), using analogies, models, and examples common to the experience of the early adolescent. Making these sessions as interactive as possible by interspersing questions and having students demonstrate various principles throughout, increases opportunities for student involvement and understanding. Without excellent preservice instruction on the subtleties of this method, many new teachers revert to what they have experienced most — the full class monologue, which turns students off to science.

Science teacher education programs for the middle grades also need to focus on strategies specific to the teaching and learning of scientific principles. Thus prospective teachers can begin to learn how and under what circumstances one uses various analogies and models to better elucidate scientific ideas. For example, the use of water flowing through a pipe as an analogy for the flow of electrical current can help students better understand electricity. However, this analogy can also induce certain misconceptions about electricity. Understanding the power and limitations of such tools is important for prospective teachers to begin to do during their preservice education.

Teachers must not only understand impo nt scientific principles, but also be able to predict which ones will be difficult for early adolescent to learn. Prospective teachers need to understand the significance of research on student misconceptions and alternative frameworks. It is not enough to know that middle grades student will have difficulty with abstract concepts in genetics. It is necessary to have strategies for assessing student thinking about such concepts so as to better plan instruction for them.

Various analytical skills relating to science curriculum are also necessary. What activities better fit the abilities of a particular group of students? Which will best stimulate student thinking? How can a text-based program be used to maximum benefit? These are questions that prospective teachers can begin to address in their preservice programs.

Recommendation:

Programs that educate prospective middle grades science teachers must include a set of experiences which help prospective teachers achieve an understanding of and facility with instruction specific to the nature of middle grade students and their science curriculum. They should be able to implement strategies that:

- **capitalize on and complement the social nature and cognitive abilities of their students,**
- **keep students interested in and excited about science,**
- **involve students in actively making sense of major scientific and technologic concepts, skills and attitudes, and**
- **address the learning needs of widely diverse students.**

Field Experiences

> [Preservice teacher preparation] programs should require early and continuous field experience in a middle level school, beginning in the freshman year of training and continuing, with a gradual increase in instructional responsibilities, until the student-teaching experience in the senior year. In all these settings, the field experience should be supervised by a qualified, experienced master teacher who has had specific training in supervisory techniques and the collection of information about teaching behavior (National Association of Secondary School Principals' Council on Middle Level Education, 1985).

No matter how exceptional the coursework in pedagogy, it is meaningless without some tie to the real world of middle grade science teaching. Hoffman and Edwards (in Fullan, 1985), in reviewing research and theory on teacher preparation, identified one critical defining property of a clinical teacher education program: school context. Every phase of a program should include field related involvement. Coursework in pedagogy must be based upon and linked with experience in middle grade settings. Just as it is necessary for young adolescents to construct their own meaning of scientific principles, it is also necessary for prospective teachers to do the same relative to pedagogic principles. This cannot be accomplished with a program conceived, taught, and based solely in the university classroom.

Yager and Pennick (1990) recommend clinical experiences throughout the education program, concurrently with academic and pedagogical coursework. Such experiences are necessary as a major component of science teacher education programs to link coursework in professional education to the world of the practical. They serve to assist novice teachers in the development of awareness of the middle grade learner and successful curriculum and instructional practices for the middle grades. They provide the context within which instruction in methods classes can begin to make sense. They supply the grist for developing prospective teachers' knowledge of pedagogy. It is that experience without which university instruction is meaningless.

Because of its pivotal role, school experience must be planned with a mind toward integration into the entire university program. Experiences with individual youngsters should coincide with course topics, so that preservice students can ascertain the early adolescents' understanding of science concepts, can tutor them on various topics, and can discover aspects of their general nature, including their likes and dislikes. Both small and large-group teaching experiences must coincide with methods coursework, giving meaning and practice to theories of curriculum and instruction. Having the opportunity to observe and then serve on a teaching team is another important experience for a prospective teacher.

With the increasingly more intensive and responsible field experiences described above, student teaching need no longer loom as a seemingly impossible challenge to the prospective teacher. In fact, the idea of the student teaching semester can be seen as one more step in the direction of becoming a teacher, especially when an internship and/or supported induction period is yet to come. However, as Fullan (1985:7) notes, the "practicum" in most preparation programs is badly in need of revision. The ideal situation is one in which joint faculty-school and school district projects "use fewer placement sites, select them for their special characteristics, address equally the goals and needs of student teachers and cooperating teachers (and their school goals), and stress the reciprocal relationship between practice and theory." Such a site could be described as a professional development school (Holmes Group, 1986; Schlechty et al., 1988), in which teachers and university faculty share the responsibility for educating teachers, participating as partners in all of their field experiences, from early observation opportunities through a supported mentor program for beginning teachers.

The idea of a supported induction program is becoming more and more common as a means of easing beginning teachers into their roles as full-time teachers. Twenty-two states have recently instituted induction programs (Capper, 1988), and even where they are not mandated, many school districts are developing them.

The University of New Mexico and the Albuquerque Public Schools, for example, have designed a collaborative, no-cost (to either university or school district) beginning teacher program for elementary teachers. Graduate student interns are placed as teachers in elementary schools and master teachers from the school system are released to serve as clinical support teachers providing consultative and nonevaluative support. This support includes in-class teaching demonstrations, materials collection, emotional and instructional support, and inservice workshops (Huling-Austin, 1986).

The Toledo (Ohio) School District has a joint school district-teacher union effort to provide ongoing monitoring and assistance to beginning teachers. The Toledo Intern Program combines appraisal of and assistance to new teachers during the first year of a two-year provisional contract. The goals of the program are to: identify and retain the best quality teachers, support new teachers with the experience that excellent veteran teachers can provide, and contribute to teacher professionalization by promoting peer evaluation. Designated "consultants" from among experienced teachers provide intensive monitoring and support to new teachers through observation, conferences to discuss the observations, and varied other support activities (Maryland State Department of Education & Research for Better Schools, 1987).

Good induction programs have:

1. well chosen, well trained mentor teachers who are both models of good teaching and supportive adults. 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. New teachers need to observe their mentors as much as their mentors need to observe them. 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 are given the assignments least wanted by veteran teachers, but what they really need is the opportunity to master the tasks of teaching in a less difficult environment.

We argued earlier for increasingly more collaboration between university and schools for the preparation of teachers. With the university taking primary responsibility for undergraduate teacher training and the school district taking primary responsibility for staff development, induction programs are the point at which it makes sense that the responsibility be truly shared. Universities can help beginning teachers continue to grow in their knowledge about teaching and the profession, but inservice teachers play a critical role in helping new teachers put their knowledge and skills into practice and reflect on their experiences. Putting inservice teachers in the roles of mentors and clinical faculty of universities helps to legitimize the all-important "on the job training."

Recommendation:

Middle grade science teacher education programs should include a carefully designed continuum of structured experiences in middle grade settings. These experiences need to begin early in the candidates' programs and involve the development of mentor relationships with expert

science teachers. The responsibility for field experiences needs to be shared by universities and schools, with schools taking on increasingly more responsibility as the prospective teacher moves into the first year of teaching.

Institutional Conditions Necessary for Programs to Flourish

Teacher education for middle grades science is the responsibility of many, especially those university personnel charged with teaching courses at the undergraduate level. However, in most programs today, there is little coordination or communication between the education and science faculty responsible for teaching such courses. The educators who advise students to take particular science courses often do so with little knowledge of what goes on in those courses beyond the information offered in the university bulletin. Science faculty rarely understand the needs of prospective teachers, and often serve as negative role models for their future teaching. Very rarely do science and science education faculty discuss the needs of prospective teachers, much less coordinate experiences that would help them improve their concept attainment.

Compounding this communication problem is the typical university reward system, which too often places a low priority on good teaching and coordination with other faculty members. In fact, many young science faculty seeking promotion are cautioned not to get involved with teaching projects, for they can detract from research. At times it is only when senior faculty are fully promoted or near retirement, perhaps becoming more philosophical about what is important, that some feel free to become involved with the problems related to teaching and the role that good science instruction at the university can play in improving science education in schools.

Within universities the development of respect for teaching as a worthwhile goal is of fundamental importance. This will necessitate a reward system different from the one now in place which focuses primarily on research and publication for promotion. Science faculty interested in teaching, research, and development related to instruction need to be encouraged to continue and expand this important work.

Even worse than the lack of intra-university collaboration is the lack of involvement of inservice science teachers in preservice programs. Other than serving as field placement supervisors, classroom science teachers are often ignored as a potential resource in teacher education programs. If science teacher education is to improve, this situation cannot continue.

To develop a true partnership between universities and public schools, a new sense of public responsibility for teacher education is necessary. This will necessitate consciousness raising on the part of all as to the shared responsibility for improving science education. Such a change has begun to occur in the private sector over the last few years, with many corporations donating time and money to teacher education and school improvement. As an example, DuPont and Monsanto, both large chemical companies, sponsor science teacher participation in professional conferences, the development and implementation of various curricular packages, and the use of staff scientists for school talks and demonstrations. A similar revolution in thought must occur in colleges and universities regarding the initial preparation of teachers.

Additionally, university and school personnel must band together to help create higher quality teacher education programs. Teachers who experience the real world of working with students can best bring the realism of the classroom to preservice teachers. Involving classroom teachers in programs will require a breaking down of traditional academic walls to allow public school personnel equal status in planning and teaching such programs. It also requires that school systems take more responsibility for the initial preparation of teachers and will require changes to allow master teachers time and appropriate rewards for this involvement.

As noted earlier, the National Science Foundation has funded several colleges and universities to improve middle grades science teacher education programs. At the University of Georgia, both planning and teaching responsibility are shared between science and education faculty as well as with classroom science teachers. Science and education courses for three consecutive terms are taught in the same classroom in a back-to-back fashion which promotes sharing. A teacher from the local schools cooperates in the planning and leads one two-hour session per week. The purpose of this "tryday" is to create a bridge between science content and teaching methods. Students perform hands-on science activities that link the content of the methods course with that of the science course. They then have the opportunity to discuss potential student learning problems, as well as practical implementation difficulties, with a teacher who actually uses such activities.

Recommendation:

Science and education faculty must work together with public school personnel to create the kind of teacher education programs described in this document. This requires the establishment of appropriate structures, including new incentive and reward systems, so that the best university and public school personnel become involved in such work. Furthermore, courses in these programs should be taught by scientists, science educators, and public school personnel in partnership.

Chapter VI

Summary and Conclusion

Throughout this report, we have emphasized that the teacher as learner must be the focus for improving middle grades science education, but that this teacher development can only occur in tandem with organizational development. One without the other cannot produce lasting, meaningful change. When teacher and organizational development are linked to build on and enhance each other, we can begin to transform our ways of thinking about learning and make broad, systemic change and improvements in middle level science education.

Perhaps the best way to summarize our report is to return to the questions raised in Chapter 1, and see how they have been answered. Then, perhaps, the answer to the big question: Where do we go from here? will become clearer.

What do teachers need to know, believe, and be able to do to meet the science and other learning needs of young adolescents?

We believe there are several areas in which teachers of young adolescents need special knowledge and skills. First, they need knowledge of middle grade students. They need to know about the intellectual, psychological, social, and physical development of young adolescents. They need to understand individual learning styles and cultural differences of their students, as well as how they think about and learn science. Second, teachers need knowledge of science and technology content and skills in "doing" science. They need a deep understanding of such major concepts as: cause and effect; change and conservation; diversity and variation; energy and matter; stability and equilibrium; models and theories; scale; structure and function; systems, subsystems, and interactions; and patterns, rhythms, cycles, and symmetry. Teachers need to understand fundamental principles of science and technology, scientific processes, and the relationship of science and technology to society.

Further, middle grade teachers need knowledge and skills in science pedagogy, general pedagogy, classroom management, and pedagogical content knowledge. They must be able to transform their science knowledge and make it accessible to their students. They need to use active and cooperative learning techniques, make teaching science an interdisciplinary endeavor, and involve their students in the development of higher order thinking skills. Because instruction must be fundamentally different than in a "traditional" setting, teachers need to know about different forms and purposes of assessment, and different techniques for classroom management.

Teachers also need to understand the concept of the middle school, with its small communities of learners and an interdisciplinary approach. Working towards a middle school concept, although they may currently teach in a more traditional setting, requires a sharp set of interpersonal and communication skills for working well with other teachers, students, students' families, and community workers.

Finally, teachers need to have a professional attitude and commitment to their work and to their middle grade students. They need to be enthusiastic and goal-oriented.

Few teachers currently, through either pre- or in-service programs, have the opportunities to develop fully these attributes of exemplary teachers of middle grade science.

What development opportunities do teachers need to change or refine the knowledge, beliefs, practices, and classroom environments current research finds to be so critical to the science learning of middle grade youngsters?

Staff development opportunities for teachers must help them acquire the knowledge, skills, and beliefs described above. They must mirror or model the kinds of learning opportunities teachers are encouraged to use with students. Teachers need the opportunity to make sense of their experiences, construct meaning from new information, and form theories to explain the worlds of teaching and learning, as well as science and technology.

Some staff development should focus on the nature of middle grade students and how they learn, with ideas for appropriate instructional strategies and techniques. Some should focus on interpersonal skills helpful in working well with young adolescents. Scientific conceptual knowledge and the roles of science and technology in society are important foci, particularly when coupled with attention to how the developmental level of students influences how they are addressed. Staff development opportunities should allow teachers sufficient and appropriate experiences to incorporate new ideas and materials into their own knowledge base and teaching strategies.

The most effective staff development approaches:

- are continuous and on-going,
- provide opportunities for teachers to choose among staff development options that match their interests, stage of development, and competence,
- provide opportunities for teachers to examine and reflect on their practice and their schools and work together to formulate new and better learning opportunities for their students, and
- model the constructivist perspective on learning.

While good staff development opportunities are critical, they are not sufficient for lasting change to occur. The changes we are recommending are too broad-based and complex. We must address institutional development as well if we hope to improve middle level science education.

What organizational features and structures do teachers need to change or refine the knowledge, beliefs, practices, and classroom environments so critical to the science learning of middle grade youngsters?

The school itself must be the unit of change if science education is to improve; it is only at the school level that science learning can be related to other disciplines in ways that are meaningful for a particular group of middle grade students. Within the school, several characteristics are essential for real change: 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; teacher involvement in decision-making; and leadership and support. Further, the school should exhibit characteristics of the middle school concept: integration, exploration, guidance, differentiation, socialization, and articulation.

Strong leadership — at the building, district, and state level — is essential for fundamental change to take place. Effective leaders have a clear and compelling vision, a proactive leadership style, strong communication networks, and flexible strategies for achieving consistent long range values and goals; they reflect on practice and possible alternatives while maintaining action amid uncertainty. To improve science learning in the middle grades, effective leaders need an understanding of how schools can be designed to address the needs of young adolescents. They need an understanding of the importance of a curriculum that promotes depth in student thinking and problem solving. These leaders need a clear understanding of the nature and ingredients of good science teaching. And they need to be collaborative.

Because few school leaders currently function as instructional leaders, training and support are necessary. The challenge is to provide leadership development opportunities that directly support good science teaching and indirectly provide an organizational context in which effective middle level approaches can thrive. The training must:

- include progressive views of organizational leadership,
- include more specific attention to instructional leadership,
- directly address the administrative and organizational conditions needed to support good science teaching in schools designed for young adolescents,
- help leaders assimilate and apply critical factors needed to implement such important educational programs, and
- include strategies for shared leadership.

Finally, new curriculum that is flexible and adaptable is needed to support teachers and schools as they implement new middle level programs. Such module-format curriculum would:

- be organized in interdisciplinary units where science and technology have been combined with other subjects,

- provide alternative instructional strategies to offer choices to both staff and students,
- include examples of actual student responses to show teachers how typical students respond to the curriculum,
- contain a variety of techniques to measure student outcomes, and
- be written to incorporate some level of local adaptation.

How can prospective science teachers best be prepared to participate fully in good programs for middle grade youngsters?

Prospective teachers need programs that integrate content and pedagogy, offer the opportunity to reflect upon their practice as teachers, and take a constructivist approach to teaching and learning. Prospective science teachers need a broad background in the humanities, social sciences, mathematics, and the fine arts in order to help design interdisciplinary and connected units of study. At least two years of undergraduate study should focus on this broad background. Teachers also need content depth in at least one field of science, although two subject-area specialization is often recommended for middle-level teaching.

More important than how many science courses are taken, however, is the nature of university science courses themselves: they need to model good pedagogy. The best and most appropriate science courses for prospective teachers:

- teach science the way that it is practiced,
- are interdisciplinary and connect their field to related fields,
- ground the discipline in its philosophical assumptions and context, and
- help students relate the content to societal issues.

These courses would focus relatively more time on fewer concepts than traditional courses and would require close collaboration with professors of disciplines other than science. They would prepare teachers with basic facts and principles of science and thinking skills and the ability to access additional information when needed.

Prospective teachers also need to understand the nature of the students they hope to teach. Good programs for teachers of middle grade youngsters provide grounding in:

- the intellectual, physical, social, and emotional nature of young adolescents,
- basic theories of learning underlying methods of teaching young adolescents,
- the nature of schooling in general and the middle school concept in particular, and
- the importance of the community and culture as they relate to schooling.

Teachers need to develop interpersonal and leadership skills for their multiple roles as managers, leaders, role models, advisors, language teachers, and as collaborators with a wide variety of people.

Prospective science teachers also need a thorough knowledge of pedagogical principles that promote science learning at the middle grade levels, including strategies that:

- complement the social nature and cognitive abilities of students.
- keep students interested in and excited about science.
- involve students actively in making sense of scientific and technology concepts, and
- address the learning needs of widely diverse students.

Prospective teachers need increasingly more involved, involving, and responsible experiences in the school context itself, through extensive field experiences in middle level schools during their entire academic training, not just through a final student teaching semester.

Where Do We Go from Here?

Throughout this report, we have indicated the elements we believe are necessary to implement good science teaching and learning at the middle grade level. Clearly, what we need and what we currently have are, in many cases, worlds apart. We believe that several actions will help us close this gap and improve science education for all middle grade students.

First, we need action research to document the transition to new forms of programs. We need to see what works best in what contexts so we can make more context-specific recommendations. As implementation occurs, we can indicate which implementation factors are critical and what program configurations are most likely to be successful. Through action research, we can identify the curriculum content, instructional processes, and learning patterns characteristic of good middle level science programs.

Because a major premise of the middle school concept is the organization of academic disciplines around an integrated core that focuses on essential knowledge, we need a clearer view of this integrated curriculum, and a national focus on this and the conceptual similarities among the disciplines. We recommend a national review and synthesis of the common elements in the various academic disciplines to help middle level programs integrate a core curriculum while maintaining the vitality of good science approaches.

The changes teachers and administrators need to make are so profound; thus it is unlikely they will occur in today's schools without external support and assistance. Staff rarely have the kind of expertise that is called for to initiate and sustain major reform efforts without assistance. Therefore, we recommend the establishment of regional academies that will address staff, leadership, and institutional development for schools serving middle grade youngsters. These academies would offer:

- full or partial academic year on-the-job training.
- intensive summer institutes focusing on teaching and leadership strategies.

content, science and technology curriculum development, and alternative assessment approaches,

- varied on-site technical assistance approaches, and
- a depository of curriculum materials and teaching aids.

Offerings would be tailored to the needs of a particular schools, district, or group of staff. In addition, we believe that states and districts can best support the needs of schools and their staffs through the development of comprehensive structures and support systems with:

- shared purposes, goals, and frameworks for good science programs,
- cross-role teams for planning, decision making, and coordination related to new science programs,
- links to teacher certification and assessment,
- appropriate student assessment approaches, and
- comprehensive support structures for staff development (including leadership development).

Finally, we believe that in order to create the kinds of teacher education programs described in this report, science and education faculty at colleges and universities must work collaboratively with public school personnel. New incentive and reward systems need to be established to assure that the best personnel at these institutions become involved in this important work. Courses in these teacher preparation programs must be taught by scientists, science educators, and public school personnel in partnership.

Clearly, the reform of middle grade science education requires a systemic approach — one in which all levels and components of the education community share the same purposes and vision of the future. The directions we have recommended — combined with those of the Center's curriculum and assessment reports (Bybee et al., 1990; Raizen et al., 1990) — constitute some starting points on a long, but ultimately rewarding road to change.

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Teacher Development and Support Study Panel

Susan Loucks-Horsley, *Chair*
Associate Director
The National Center for Improving Science Education
Andover, MA

Jackie Grennon Brooks
Adjunct Professor
Hofstra University and Teachers College
Columbia University, NY

Maura O. Carlson
Research Associate
The National Center for Improving Science Education
Burlington, VT

Paul Kuerbis
Project Director
The National Center for Improving Science Education
Colorado College
Colorado Springs, CO

David D. Marsh
Associate Professor
School of Education
University of Southern California
Los Angeles, CA

Michael J. Padilla
Professor of Science Education
The University of Georgia
Athens, GA

Harold Pratt
Executive Director for Science and Technology
Jefferson County Public Schools
Golden, CO

Kitty Lou Smith
Middle Grade Teacher
Fairfax County Public Schools, VA

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University of Wisconsin
Madison, Wisconsin

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National Science Supervisors Association
Glastonbury Public Schools
Glastonbury, Connecticut

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Mathematics, Science and Environmental Education
California Department of Education
Sacramento, California

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General Director for
Regional Personnel Administration
General Motors Corporation
Warren, Michigan

Richard M. Berry
National Science Foundation (Retired)
Bowie, Maryland

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Science Teacher and Lower School Head
Shady Hill School
Cambridge, Massachusetts

David Kennedy
President
Council of State Science Supervisors
Olympia, Washington

Jerome Pine
Professor of Biophysics
California Institute of Technology
Pasadena, California

Mary Budd Rowe*
Professor
College of Education
University of Florida
Gainesville, Florida

F. James Rutherford
Chief Education Officer
American Association for the Advancement of Science
Washington, D. C.

Mare Taagepera
Director
Science Education Program
University of California
Irvine, California

* Currently Professor, School of Education, Stanford University

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