Ohio's Vision for Science Education in the Twenty-First Century

Peter W. Hewson
University of Wisconsin-Madison

Prepared for the Ohio Mathematics and Science Coalition, June 2001

TABLE OF CONTENTS

INTRODUCTION

The start of a new millennium is the right time to look ahead and dream about the future of Science Education in the state of Ohio. In this vision, *all* students will be learning science with understanding and purpose; in doing so, they will be excited about what they are learning. All science teachers will teach their students with enthusiasm and competence to achieve these goals through professional practices that are deeply rooted in the disciplines. All schools will be communities that support students and teachers in their ongoing learning through suitable resources and coherent, responsible policies, and that are in turn supported by all stakeholders in the communities in which they are located. A vision of the future is needed to convince Ohioans that there is something worth striving for, to galvanize into action the stakeholders in OhioÕs science education system, and to direct the efforts that will make the vision a reality.

Looking ahead and envisioning the future of Science Education in the state of Ohio is essential. Creating a vision isnÕt, however, enough, no matter the clarity and detail with which it is stated. Achieving the vision is a very different enterprise that requires much more than the vision itself, essential though that be. It requires a knowledge of the *status quo*, of where we are and what we are. Getting to the State House in Columbus is a very different matter if we start from Dublin, Ohio or Dublin, Ireland; if we only have our muscle power or if we have gasoline powered engines. Achieving the vision also requires pathways that connect *status quo* to vision. This focuses our attention on the journey: the possibility of alternative routes, the resource needs along the way, and the time it takes to get there all need to be considered. Thus the start of a new millenium is the right time not only to envision the future, but also to take stock of the present, and to do so in light of the past.

Taking stock is to recognize that this is a dynamic world. What was once state-of-the-art is now an every day occurrence: flying non-stop across the Atlantic was an impossible dream for the Wright Brothers, a heroic achievement for Lindbergh, and is today a daily occurrence for thousands upon thousands of travelers. The dynamism of the world is, however, more than being more efficient. The very nature of the world is changing and thus, what was once a solution can become an obstacle in different contexts. When people lived in isolated communities simply obtaining and providing good information was a constant challenge. In the world of today, however, we are awash in huge quantities of information; the challenge is to select and apply what we need.

> If America is to remain a middle-class society in the high-tech global economy, the schools in every region of our nation must graduate all their students--not merely the top fifth--with new and far higher skills than were necessary in the past.
> (Hershberg, 2000, p. 32).

Taking stock is also to recognize the challenges of the future. There is little debate in Ohio, in the United States, and around the world that our future well-being depends on how well we educate all students in science. The present economy demands a much higher percentage of scientifically literate people than has been the case in the past. In particular, a failure to strengthen our scientific and technological communities could compromise our national security (U.S. Commission on National Security/21st Century, 2001, p. 39). Scientific and technological advances in the future will depend on enhanced expertise and creativity, and this in turn requires strengthened connections between what happens inside and outside of school, because Ò[n]ever before in history has the link between economic well-being and education been strongerÓ(Hershberg, 2000, p. 32).

Taking stock also means identifying problems with the *status quo*: initiatives that have been unsuccessful, mistakes that have been made, and opportunities that have been missed. We need to improve the quality of learning of our students. That they have not reached the National Goals of being first in the world in science and mathematics by the year 2000 is highlighted by the Third International Mathematics and Science Study (or TIMSS) In 1995 TIMSS tested students in 41 countries around the world. At the 4^{th} grade level U.S. students were above the international average in both mathematics and science. By the 12^{th} grade they were below the international average in both science and mathematics. Thus, in comparison with other countries, the performance of U.S. students deteriorated in both mathematics and science as they progressed through school. The picture is no better in Ohio. Several different measures indicate that in comparison to other states, OhioÕs students perform at an average level in science. This means that we need to improve the quality of teaching. Too frequently, science is taught by teachers who are under-qualified in these disciplines, who use methods that have not kept up with the pace of innovation, who are isolated from their peers and administrators, and who have little access to opportunities for professional advancement (National Center for Education Statistics, 1997, p.26).

University of Cincinnati Public Opinion Survey
Of those surveyed in Ohio, over 90% agreed that science should help students make sense of the world, over 80% agreed that science has value in the workplace and will improve studentsÕjob opportunities, and over 70% agreed that basic skills in science have changed over the past 30 years.
(Evaluation Services Center, 2001)

Taking stock also means recognizing the achievements of the past and present, and the pathways that have led us to this point. These are resources that are available for the next stages of the journey, the capital to invest for the future, the foundation supporting the new vision that will be constructed. By all measures, some students, some schools, some colleges, some systems have done, and continue to do, extraordinarily well. Over the past 30 years, of the people who have won Nobel Prizes in Physics, Chemistry, and

Medicine, 49% received a major component of their education in the U.S., and 59% were employed in the U.S. (Nobel Foundation, 2001) In this supreme standard of excellence, the U.S. has and continues to dominate. At the college level, U.S. universities consistently draw the best students in the world to study in higher education. There is no question that they come because of the excellence of the education they receive. It is also the case that in businesses and industries that depend on science and mathematics to innovate, the U.S. leads the world. U.S. companies dominate the computer world, and the aircraft and aerospace industries, and produce a major proportion of medical advances. The abilities to create, to innovate, to develop, to apply are at least as well represented in this country as in any country in the world. At the K-12 levels, there are also wonderful examples of students who excel in ways that would have been unimaginable a decade ago (Smith, Maclin, Houghton, & Hennessey, 2000), teachers who motivate all their students to achieve extraordinary outcomes (Beeth & Hewson, 1998), school systems that challenge all their students to expect to be successful (American Institutes for Research, 2001; Kelly & Kahle, 2000; Roberts, 2001), and programs that have been designated as exemplary models (U.S. Department of Education, 2001). In other words, scattered all across this country, there is a great deal of extraordinary achievement in science, and activities that depend on these disciplines. There is a culture of excellence that drives creative innovation in a thousand different directions. The challenge is harnessing this energy for all students rather than a few.

Taking stock is to recognize that getting to where we want to be is not just a matter of identifying goal states, essential as that is. We also need to understand the *status quo* and connect it to our goals along pathways of continuous improvement. The *status quo* exists for a variety of reasons. To the extent that it is unsatisfactory, it is not that it is intentionally so--no one is trying to do a bad job. Rather, when many different features of complex systems interact with each other in unforeseeable ways, they often produce consequences that were not envisaged in the development of the system. Also, some outcomes that might have been desirable at an earlier time, in a different context, are no longer so. Some of these features may even, on the face of it, seem to have little relevance to where we want to be. In other words, taking stock is to recognize that getting from where we are to where we want to be requires much more than knowing the desired endpoint. It also requires a detailed knowledge of what our starting point is and why we are where we are; an identification that within the *status quo* there are both barriers to progress and opportunities to facilitate change; a realization that change of necessity has to start from the *status quo*, that many of the required changes may seem to have little explicit, direct influence on the process and progress of reform, that there will need to be many, parallel initiatives along alternative pathways, and above all that it will take time.

Taking stock is, finally, to recognize that many different people and structures and processes play significant roles in why science education is as it is in Ohio today. They will also be partners in all endeavors to achieve the vision. In doing so they will need to utilize their existing resources at the same time that they adapt to changed contexts and goals. Each of these roles is not of course played out in isolation: they interact with each other, influencing their future development in ways that facilitate some directions and constrain others. In short, they constitute a system. This document, as a result, considers the components and characteristics of educational systems, such as OhioÕs, before outlining the vision, detailing the *status quo*, and presenting recommendations designed to connect the former to the latter in achievable ways.

EDUCATIONAL SYSTEMS

Educational systems are complex. While the purpose of an educational system--educating students--is straightforward, many different people, each carrying out a variety of functions, are involved. The influences of each person and each function on student learning are also extremely varied. Describing an educational system thus means recognizing its structure (its component parts) and its function (detailing the ways in which these parts interact with each other).

The focus of this document is on the system of education in the state of Ohio. This is not, however, a single, unitary system, but rather a system comprised of coupled subsystems. At times it will be better to focus on these smaller subsystems, such as classrooms and school districts, when the primary point of interest lies within the subsystem. When, however, the point of interest is outside a subsystem, a larger system will be the focus of attention.

Structure of the Educational System

The structure of Ohio's educational system is described here in terms of its personnel and the major attributes it needs to address. Taking into account that this is a system that includes many subsystems, it is necessary to consider the different Organizational Levels that define systems of different sizes. These range from classrooms, schools, and districts, through regions and the states, and on to nations and the world. In this document, the national and international levels will not be emphasized.

Personnel

Because education is, at its heart, a human, social enterprise, the description of its structure needs to be expressed, in part, in human terms. The people concerned about and involved in education comprise three major categories. These include:

- **Students**. Students are the focal point of the system. Without an expectation that there are students in the system who will learn--in this case, learn science--it cannot be an *educational* system.
- **Educators**. Educators are those whose primary occupation is education. The most significant of these include teachers; administrators at school, district, and state levels; educators of teachers and administrators; and members of professional organizations
- **Educational Partners**. Educational partners are people who have a significant interest in education, but whose primary occupation is not education. The most significant of these include parents of students, members of the community in which students live; people in businesses and industry (both private and public); and policy makers.

Major Attributes

These attributes are arranged in terms of organizational levels. Many of these attributes are relevant to different levels, but are included under the most appropriate level. Some attributes are general across all levels and these form a separate category.

Attributes that are focused on the **Classroom** are related to Student Learning and Performance and include:

- Students and their Learning
- Teachers: Characteristics, Roles, Competencies
- Curriculum Implementation
- Instruction
- Assessment
- Science

Attributes that are focused on the **School District** are related to Teacher, Administrator, School & District Development and Performance and include:

- Teachers: In-service Education
- School Environment and Culture
- Curriculum Planning/Design/Alignment
- Technology
- Resource Allocation
- Public Support

Attributes that are focused on the **State** are related to State Development and Performance and include:

- Standards
- Accountability
- Teacher Certification

Attributes that are **General** across organizational levels include:

- Commitment and Autonomy
- Pathways for Development and Continuous Improvement
- Coherence and Continuity

Comments on the Structure

While the interests of people concerned about education probably range across most, if not all, levels, their principal involvement and primary influence will be at one or two levels. For instance, students and teachers are principally involved at the classroom level whereas state policy makersÕ primary influence will be at regional and state levels. These different foci are summarized in the following Personnel-Organization Chart.

Primary and Secondary Involvement of Personnel at Different Organizational Levels

Personnel		**Organizational Level**		
		Class-room	**School District**	**State**
Students			x	
Educators	Teachers			
	school administrators	x		
	district administrators			x
	state administrators	x	x	
	educators of teachers		x	
	educators of administrators			x
	members of professional organizations	x	x	x
Educational Partners	parents of students			
	community members	x		
	people in business and industry			x
	policy makers	x		

Primary involvement x Secondary involvement

Function of the Educational System

A system is more than the sum of its parts: it is the interactions between its parts that make it a system rather than a collection of parts. This may be an obvious point: when the parts of a system are specified, most people will assume that they interact with each other. People are even likely to have ideas, perhaps implicitly, about the nature of those interactions. It is, however, important not to take these interactions for granted and assume that the form they take is obvious. A different form of interaction between two key components of a system can have a major impact on how the system functions. The following illustrations point to the nature and scope of different relationships in educational systems, and to the importance of specifying them in some detail.

The central relationship in an educational system is that between student and teacher, and their actions of learning and teaching. For many, this relationship is straightforward and causal: a teacher teaches a topic and as a direct outcome of these actions, a student learns what was taught. One outcome of this perspective is that if students fail to learn, teachers need to be held accountable for this failure. An analysis of the concept of teaching (Fenstermacher, 1986; Hirst, 1971) demonstrates, however, that the relationship between teaching and learning is ontological rather than causal. One cannot conceive of teaching without, of necessity, also thinking of learning. Yet teachers *can* teach without all their students learning, and students *can* learn without the assistance of a teacher. What, then, is a teacherÕs responsibility? The analysis demonstrates that teaching, in this case of science, should of necessity consist of tasks and activities that a) are intended to help particular students learn particular content (propositional, procedural, or attitudinal), b) express or embody this particular content to be learned, and c) reasonably connect the desired content with the present state of the learner (Hewson & Hewson, 1988). These specify teachersÕresponsibilities. It also demonstrates an important distinction between the tasks of learning (what a learner does, the process of learning) and the achievement of learning (the result, outcome, or endpoint of engaging in the tasks of learning). In other words, a teacherÕs responsibility is to ensure that his or her students are engaged in the appropriate tasks of learning. It is the learnersÕresponsibility to engage effectively with these tasks and thus to achieve learning. This relationship is primarily located at the classroom level, it involves students and teachers, and it concerns the major issue of student learning.

Another set of relationships, viz., between curriculum, instruction, and assessment builds off this relationship between teachers and learners, and thus between the tasks and activities of teaching and learning in which they respectively engage. The need for curriculum (what is taught) to be congruent with instruction (how it is taught) was explored in the previous paragraph. While everyone would agree that curriculum and instruction, not to mention assessment, should be aligned with one another, this does not happen automatically. In fact, research on current practice demonstrates that frequently the implemented curriculum lacks coherence with the intended curriculum, and assessment lacks coherence with both. Alignment does not naturally happen on its own. This has been recognized by the centrality of aligning curriculum, instruction, and assessment in calls for systemic reform over the past decade (Smith & O'Day, 1993). These relationships, concerned with the major attributes of curriculum, instruction, and assessment, are primarily located at the classroom and school levels, and involve teachers and school administrators.

Another significant set of relationships concerns accountability measures. In recent years, in response to pressures such as restlessness in the tax-paying public over school financing and the publicity of unfavorable international comparisons such as TIMSS, policy makers have advocated a range of accountability measures such as the adoption of curriculum standards (National Research Council, 1996), the institution of state-wide achievement testing, and the publishing of report cards on schools (Ohio Department of Education, 2001). This means that even though Ohio is regarded as a state with local control of educational matters, the influence of state policy makers over practices at local levels is substantial. These relationships, concerned with the attributes of standards, accountability, and assessment, are primarily located at the state level (though they entail all levels). They involve policy makers, state administrators, district and school administrators, and teachers.

The illustrations provide examples of different types of relationship in different parts of the system that operate in different ways. When seen in relationship to one another, however, they demonstrate the complicated way in which an assessment policy at state level can influence a curriculum decision at the school level. Finally because of the relationships between curriculum, instruction, and assessment, the state policy influences classroom practice.

General Systemic Attributes

Understanding, commitment, and autonomy within a coherent framework

A significant idea concerns individuals and their relationship to the systems within which they work. In particular, these individuals may be students, teachers, or administrators, and the system may be a classroom, a department or team, a school, a school district, a province or state. Frequently, what makes sense to individual participants is at odds with what makes sense at the organizational level. To illustrate, if teachers do not have the capacity to implement a new curriculum in their classrooms, given their background, expertise, and available resources, and do not believe that it will improve education, the ideals and principles of the curriculum designers will become irrelevant.

If a system and the people who constitute it are to work effectively, there are different conditions that need to be met. On the one hand, at an individual level, each person needs to believe that she or he is an important part of the enterprise, that his or her contributions are valued and respected, and that she or he has a measure of autonomy in carrying out his or her responsibilities. This means that each person needs to develop an understanding of the many facets of his or her job and become committed to the belief that it is fair, equitable and worthwhile. The organization needs to be responsive to the needs and ideas of its members, and to be trusting of their abilities. In other words, each person needs to be able to take ownership of the position to which she or he is appointed, and the work that this entails.

On the other hand, at an organizational level, if the system itself is to operate effectively, there needs to be coherency in its vision, a concerted working together to achieve common goals, and a lack of different groups working at cross purposes to one another. This requires leadership to create a vision, set goals to be achieved, and develop strategies for reaching those goals. One of the key strategies needs to be the effective communication of the vision to all participants in the system. Individuals, then, can come to see that their efforts are responsive to, contributing to, and fitting in with, an overall vision.

Bringing a system together such that what makes sense for the participants is coherent with what makes sense for the system does not happen of its own accord. There need to be strategies in place that allow reconciliation of these different perspectives to occur as a normal part of the functioning of the system, whether it be a classroom, a school district, or teacher professional development. In other words, this is a critical attribute to consider if the Vision is to be successfully implemented.

Pathways: Development and Continuous Improvement

In considering any long-term endeavor--such as implementing a Vision of the System--it is necessary to consider both the outcomes that the endeavor seeks to achieve and the means, the processes, the pathways by which those outcomes will be achieved. It is seldom that outcomes are ignored; much more frequently, however, it is only when desired outcomes are not achieved that the pathways by which they might be achieved are considered. The likelihood of achieving success in an endeavor is, however, greatly enhanced if the pathways are explicitly included in the design of an endeavor. The pathway metaphor itself is valuable because it suggests several important issues. First, it draws attention to the starting point, the endpoint, and the various ways by which they might be connected. Without knowing where one starts from, and identifying reasonable connections between various points along the way, the possibility exists that we will find ourselves on the wrong side of a chasm to be bridged that requires more resources than are available. Next, the pathway metaphor suggests the need to pay careful attention to the journey and the resources that are likely to be available along the way. In other ways we need to understand the system components that facilitate progress along the pathway. Finally, the idea of a pathway draws attention to the time that will be needed to complete the journey. It does not happen instantaneously; specifying milestones along the way reminds us that this is the case.

There are several comments to make about pathways. First, in considering pathways, we need also to consider that the pathways may be those traversed by both people and systems. Students, teachers, administrators, parents, members of the public are all likely to be relevant as we consider learning pathways. But systems will also need to travel along accessible pathways, whether these are classrooms, schools, districts, local or state-level organizations. Second, the people and systems traversing the pathways may not remain unchanged by the journey: the process can be developmental such that at the conclusion of the journey, the people and the systems involved may be very different from when they started. Third, the pathway may not be linear, but cyclical in which important places are revisited, perhaps systematically so, in order for continuous improvement to occur. We may not get it right first time, but through reflective refinements we continue to improve.

Coherence and continuity within complex systems

Improving an educational system by its very nature is complex. This is so because it involves students, teachers, curriculum, instruction, assessment, and the classrooms in which teaching occurs. The context in which it happens adds another layer of complexity, through schools, districts, the state, and the public. This means that we need to keep in mind at least two aspects of complexity. The first of these arises from the very nature of systems: these comprise different parts and the links, relationships, and interactions between the parts. Understanding whether or not a system works therefore means paying attention to the coherence (or lack of it) that exists between different components. To illustrate, two key components of systemic reform are the alignment of curriculum, instruction, and assessment, and the development of coherent curriculum frameworks, e.g., (National Research Council, 1996). A second aspect of complexity to be considered is that of continuity over time. For example, does a system provide ordered sequences of developmental goals for students as they progress through the system?

ACHIEVING THE VISION OF A TRANSFORMED SYSTEM OF EDUCATION

The vision of a transformed system of education can only be achieved by attending to its systemic nature: its components and their interactions. This means that any recommendations for change have to be coordinated in a coherent fashion, not only across these components, but also through their interactions. Without coherent coordination, changes will likely be *ad hoc*, serving limited interests, working at cross purposes with each other, and lacking the synergy required for effective large-scale change (Newmann & Wehlage, 1995). In other words, to achieve the vision, change has to be systemic (Smith & O'Day, 1993).

From a systemic point of view, realizing the vision of transformed classrooms, schools and districts, and state institutions represents a major challenge. There are several reasons why this is so.

- There are very significant differences between where we are now--the *status quo*--and the vision of where we want to be. This means that getting where we want to be will require major changes in all aspects of the *status quo*.
- The multitude of changes are changes within systems, and therefore have to be considered systemically. If changes are not coordinated with one another, if they lack coherence across components, they can begin to work at cross purposes with each other. Thus, they could cancel one another out, or even reduce the overall functionality of the existing systems.
- Realizing the vision is a challenge because a significant property of any functioning system is its ability to be self-sustaining, to resist change, and to keep working under different circumstances. While this ability has advantages, particularly in the short term, it does have the disadvantage that if external circumstances change radically, a system may end up being obsolete and irrelevant, even though it continues to function.

Descriptions of the *status quo* are likely to rekindle familiar, comfortable memories, of events and people and systems that in many ways have worked for significant numbers of students over an extended period of time. In contrast, the images evoked of the vision may seem idealistic, ambitious, and sufficiently removed from current practice as to be unrealistic, particularly as a vision of what *all* students might be engaged in.

There are two comments to make about this contrast

- There is much about the *status quo* that is worthwhile. It of necessity is the foundation upon which educational systems in the future will have to be built, through the experience of teachers, administrators, and bureaucrats, both in their professional practice and the resources they have gathered and created. In other words, the choice is not a stark either-or, but a both-and, with an increasing emphasis toward reform initiatives.
- The question arises of why we should change a system that by many measures has been successful. There are several reasons. First, the world itself is changing at a

rapid pace; thus the degree to which an unchanging educational system was adapted to, and able to serve, its environment will inevitably decrease as the environment itself changes. Second, while the educational system works for some students extraordinarily well, it does not do so for all. As a result too many students are left behind. At a time when the employment profile of the nation is changing rapidly, with the proportions of unskilled jobs going down while those of skilled jobs are skyrocketing, ignoring this problem becomes a recipe for disaster, for both the economy and national security (U.S. Commission on National Security/21st Century, 2001).

Recommendations for change in OhioÕs education system are, therefore, outlined in terms of the structure of the system. This system is comprised of a variety of interacting components. Of particular importance are *people* (students, educators, and educational partners), and *institutions* of different organizational levels (classrooms, school districts, the Ohio Department of Education, colleges and universities, etc.). It forms a system because these various components interact with one another in mutually influential ways. It is not, however, a single, unitary system, but rather a system comprised of subsystems at different organizational levels. It is useful to focus on these subsystems when the primary point of attention lies within them; the subsystems of particular importance are classrooms and school districts. When the primary point of interest is external to a subsystem, the subsystem itself becomes an interacting component within the larger system.

Thus recommendations are outlined in terms of the **Classroom**, the **School District**, and the **State**. Within each of these sections, first the vision is introduced in a series of images, next key features of the *status quo* are outlined and contrasted with the vision, and finally a set of coordinated recommendations is proposed.

THE CLASSROOM

Vision

Imagine a classroom in which a teacher sets the stage for her students with a demonstration of a phenomenon that embodies significant concepts in a discipline, e.g., a vibrating string that resonates at different frequencies. After discussing possible variables that might influence the phenomenon, the students form into laboratory groups to investigate the effects of different variables on the phenomenon. After gathering data and analyzing them using computer tools, each group summarizes their conclusions on a portable white board. In a whole class session, the teacher selects different groups to present their white board summaries. She facilitates the discussion by inviting other student groups to ask questions, and following up, if necessary, with her own questions that frequently compare different groupsÕ responses. The outcomes are that teacher and students formulate clear statements of concepts that are central to explaining the initial phenomenon. These have arisen within the various contexts of the experimental work from detailed conversations of the merits or otherwise of different explanations of the phenomenon under consideration (Hestenes, 2001; Wells, Hestenes, & Swackhamer, 1995; Yahya, 1999).

Imagine a classroom in which students are immersed in a world of scientific inquiry into genetic inheritance. The teacher starts the unit by guiding students through a reading of MendelÕs original article, a simulation of his original data gathering, and an analysis of his results. This leads to students understanding MendelÕs model of simple inheritance to the point of being able to use it to analyze simulated field samples of organisms. Then they are presented with a field sample with anomalous characteristics, e.g., three phenotypes instead of the two explained by Mendel. They notice the anomaly and ponder their inability to explain it. They recognize their need both to understand the phenomenon better by making further simulated crosses, and to revise MendelÕs model in ways that explain the anomalous behavior. In a class conference called together by the teacher, students demonstrate that they have succeeded when they can successfully analyze and explain a different field sample with the anomalous inheritance pattern, under the scrutiny of their peers. As the teacher had intended, students were engaged in many scientist-like activities (Hewson & Lemberger, 2000; Johnson & Stewart, 1990; Passmore, Cartier, & Barton, 2001; Williams, forthcoming).

These classrooms unmistakably convey the image of science as inquiry: a search for new knowledge that arises from investigations of natural phenomena based on a foundation of what we already know (Duschl, 2000; National Research Council, 2000). Here, science as inquiry is not simply a lesson topic, but what students are engaged in (Metz, 1998). In addition to the question ÒWhat do we know?Ó students are considering questions such as ÒHow do we know it?Ó and ÒWhat does it mean to do science?Ó (Abd-El-Khalick, Bell, & Lederman, 1998)This is a dynamic conception of science that recognizes it as a human pursuit--as much invention as discovery--with a long history during which schools of thought competed and ideas changed. When scientists produced knowledge, they also needed to make judgments to decide whether or not it was ÒgoodÓ knowledge. The basis for judgment is as important a part of the class as the science knowledge itself (Cartier & Stewart, 2000).

> NCREL Teacher Colloquium
> Master Ohio science teachers believe it is critical for students to learn about science as a method of exploration and discovery, through hands-on experimentation, and that there is no substitute for actually becoming involved in the inquiry process. (Otto, van der Ploeg, & Blakeslee, 2000, p.5)

Teaching in classrooms such as these requires that teachers take on different roles (Hewson, Beeth, & Thorley, 1998). On the one hand, they set the stage for student learning. Teachers:

- choose curricular tasks that deal with significant concepts in the discipline. These tasks require students to think scientifically by making hypotheses and gathering evidence in different forms that support or refute their arguments (Newton, Driver, & Osborne, 1999).
- establish and maintain a classroom climate that supports students as they express ideas that may clash with those of their peers (and the teacher) (Duit, Treagust, & Mansfield, 1996; Fraser, 1998; Scott, Asoko, & Driver, 1992).
- introduce students to a discourse that makes explicit the basis on which scientific ideas are judged, and in which ideas are accepted or rejected not on the basis of who expressed them, but how sound the arguments are that support them (Cobb, Wood, & Yackel, 1991; Klaassen & Lijnse, 1996; van Zee & Minstrell, 1997).
- On the other hand, having set the stage, teachers:
- step out of the limelight by using strategies that support students' exploration of their own and others' ideas.
- monitor progress and facilitate discussion.

These are not easy roles to play successfully, particularly in combination with each other (Beeth & Hewson, 1998). They require that teachers have a sound knowledge of the science they teach and the typical ways in which students respond in these areas (Carlsen, 1991; Hashweh, 1987). When teachers successfully combine roles such as these with each other, their practice has been called authentic pedagogy (Newmann & Wehlage, 1995) p.13.

NCREL Teacher Colloquium
Master Ohio teachers stressed the need for students to express their ideas about math and science topics, and to build on what students bring to the classroom by discussing their ideas with them. This engages the student from the outset and validates his or her thinking.
(Otto et al., 2000, p.6)

Students in these classrooms are engaged to an extraordinary degree in the tasks that their teachers have set for them (Harrison, Grayson, & Treagust, 1999; Smith et al., 2000; Thorley & Woods, 1997; Tytler, 1998). They are expected and able to talk about what they are doing and why they are doing it (Gunstone, 1994; Hewson & Thorley, 1989). They understand that their task is to find meaning in the natural phenomena they are investigating rather than to identify the answers their teachers might want them to give. Thus they are not prepared to accept what they hear without question. They listen to their peers and expect to understand their ideas, whether or not they agree with them. They are constantly in communication with one another and their teacher. This is a process that helps them to clarify and refine their ideas, understand different implications of these ideas, and see ways in which they might (or might not) connect with other aspects of their knowledge. It is also likely that from time to time they will change their minds as they recognize that ideas other than their own are more efficient, more extensive, or better able to explain the natural phenomena they are investigating.

These classrooms images are based in reality. Each of the features described has been documented in existing classrooms and replicated in others, as have other innovative features. Classrooms such as these are not, however, a common occurrence. If you were to visit a representative sample of science classrooms, you are far more likely to encounter a rather different set of images, even if you had chosen classrooms that were fully functional by normal standards.

Status Quo

The image of science that would predominate is of an authoritative body of knowledge that is extensive, complicated, abstract, and difficult to comprehend. An unquestioned assumption would be that it was accumulated by a small number of individuals of heroic proportions, the Darwins, Curies, and Einsteins of the scientific world. Most of the knowledge would be factual, much of it difficult, and with so much of it to be considered, there would be little time for students to experience the natural world, even though this is what the knowledge is all about. Apart from brief references to a scientific method, there would be little attention to how scientific knowledge was acquired. In other words, the knowledge itself would not be questioned. In classrooms such as this, the repository for this knowledge is largely textbooks and other authoritative resources; it is these that serve to define the curriculum. Many, though by no means all, teachers will be familiar with this body of knowledge. They would not consider themselves as having contributed to it. Many of them would doubt that they had any potential for doing so. Science in these classrooms would, in SchwabÕs (Schwab, 1962) words, be a Òrhetoric of conclusions.Ó

The image of teaching that would predominate would be of a teacher-centered classroom. This image is consistent with an image of science as a body of knowledge in that teachers would see their purpose as one of organizing and presenting this knowledge as faithfully as possible. Their expertise would be evident in the skill with which they sequenced instruction, selected examples that illustrated concepts as cleanly and simply as possible, and kept students occupied with a range of tasks that embodied the knowledge and skills to be acquired that day. Their instruction would predominantly use techniques designed to present authoritative knowledge, exercises designed to clarify it, and assessments whose purpose would be to check the fidelity with which students could reproduce it. If they used demonstration apparatus, the purpose would be to illustrate what was being taught. If students engaged in practical work, they would be following carefully prescribed sequences to reach predetermined goals.

Finally the image of learning that would predominate would be of students whose purpose was to assimilate the authoritative knowledge being made available to them. This they would do by attending to teacher presentations, working through tasks and exercises whose purpose is to illustrate and exemplify curricular knowledge, and demonstrating through a variety of techniques that they can reproduce this knowledge in ways that represent it as closely as possible. This would not always be an easy task, because scientific knowledge would frequently seem to them to be complex and often counter-intuitive. Some students would understand the structure of knowledge in which scientific information is embedded, and appreciate its power. Other students would, however, see only a confusing, meaningless mass of information that made little sense to them. What they did know might be quite different from what they were taught. Even when they achieved good grades, the chances are that their understanding of the material was poor.

Various attributes of the Classroom emerging from this discussion are summarized in terms of Vision and Status Quo, followed by Recommendations for achieving the Visions with respect to each attribute.

Realizing the vision of transformed classrooms will require many changes. Because a classroom is itself a subsystem that is embedded in the larger systems of schools, districts, and the state, these many changes will need to be carefully coordinated. This is to ensure that they do not work against one another, but serve the common vision. Recommendations for change, therefore, need to form a coherent set that applies to all components of the system and their interactions. Some of these recommendations are internal to the subsystem of the classroom, and can be internally implemented. A number of them will, however, need to be implemented beyond the classroom system; these are considered further in the following section.

Students and their Learning

Summary

Vision:

- Students learn with understanding & commitment
- Students seek to make personal sense of the curriculum
- Students present sound arguments to justify the ideas they hold
- Students apply knowledge and solve problems in complex circumstances beyond the classroom
- Students understand science by doing science
- Students are active learners; independent thinkers; innovative risk takers
- Students manage as well as acquire information
- Students are self-confident, passionate, and socially conscious
- Students are able to reflect on their learning
- Students can work collaboratively, communicate effectively

Status Quo:

- Students have many ideas that differ from those they were taught, and are retained Students despite teaching to the contrary
- Students have knowledge that is fragmented
- Students have difficulty in applying their knowledge
- Students achieve poorly
- Students get good scores without understanding what they have learned
- Students learn by rote memorization
- Students have poor learning tendencies

Recommendations

Students will have to change how they learn. This will mean changing both the contextual circumstances in which students learn, i.e., their learning environment, and the nature of the work that is required of them. In other words, the opportunities for students to learn and to demonstrate that they have learned will need to be different. Thus we recommend the following:

- Students should be provided with supportive learning environments that provide opportunities to learn challenging material through curricula that focus on fewer topics, connect them to local contexts, and explore how science makes sense of the world.
- Students should be provided with opportunities to express their own ideas, compare them with other ideas, make reasoned choices between them, and take control of

their learning by being able to exercise their judgement using accepted standards of scientific judgement.

Teachers

Summary

Vision:

- Teachers are committed to students and understand how they learn
- Teachers know the subjects they teach and how to teach those subjects to their students
- Teachers are responsible for managing and monitoring student learning
- Teachers think systematically and reflectively about their practice and learn from experience
- Teachers are members of learning communities

Status Quo:

- Teachers have poor disciplinary backgrounds
- Teachers are unqualified in science
- Teachers professionally isolated
- Teachers lack professional perspective and technique
- Teachers often do not respect their own profession
- Teachers do not know how to affect an individualÕs commitment to change
- Teachers have beliefs and knowledge that do not support reform based teaching

Recommendations

Teachers will have to change the practice of their teaching. Teachers are responsible for establishing their studentsÕlearning environment, and providing them with appropriate tasks and activities. For these to change in significant ways, teachers will need to adopt different ways of thinking about learning and teaching, employ different instructional methods, and use different curricular resources. In order for this to happen they will need support of a variety of different kinds. Thus we recommend the following:

- Teachers should be provided with curriculum, instructional models, and assessment techniques that are aligned and integrated with other, encourage student learning and understanding, embody science as inquiry, focus in greater depth on fewer core content topics, are supported with appropriate resources, and are fair, equitable, authentic, and useful for all stakeholders.
- Teachers should be provided with professional development learning opportunities that support them in increasing their disciplinary knowledge, deepening their understanding of science as a process of inquiry that leads to an authoritative body of knowledge, learning curricular, instructional, and assessment approaches that are aligned with each other, and implementing these approaches in their classrooms.
- Teachers should be provided with a school and district climate that is supportive of teachers in professional learning communities (Newmann & Wehlage, 1995, p.37).

Curriculum and its Implementation

<u>Summary</u>

Vision:

- Curricula are aligned with instruction and assessment
- Curricula focus on central concepts of science
- Curricula are based on high quality science standards
- Curricula go into greater depth on fewer topics
- Curricula are authentic with connections to real-life experiences
- Curricula reflect science as inquiry
- Curricula are designed with students ideas in mind
- Teachers designs their curriculum with students' ideas in mind
- Teachers include parallel strands in the curriculum

Status Quo:

- Curricula are overcrowded and shallow (Òa mile wide and an inch deepÓ)
- Curricula are driven by text-books that attempt to serve all people
- Curricula are focused on out-dated basic skills (mathematics) and the factual body of knowledge (science) (e.g., mathematical symbol manipulation unconnected with real-life sense-making)
- Curricula focus on skills before understanding
- Curricula do not reflect science as inquiry
- Curricula are directed at finding the Òright answerÓ
- Curricula perpetuate traditional academic rituals

<u>Recommendations</u>

- **Provide** curriculum that:
  - is aligned with instruction and assessment
  - focuses in greater depth on fewer core content topics (rather than attempting to provide complete coverage of all topics)
  - embodies science as inquiry (in addition to their bodies of knowledge)
  - encourages student understanding
  - is supported with appropriate resources
- **Provide** professional development learning opportunities to help teachers implement new curricula
- **Present** data and reasoned arguments that demonstrate shortcomings of current curricula

Instruction

<u>Summary</u>

Vision

- Instruction is aligned with curriculum and assessment
- Instruction is based on inquiry, problem solving and sense making
- Instruction includes project work
- Instruction varies according to curricular goals and student needs
- Instruction is guided by research on what students know, and how students learn and think scientifically
- Instruction incorporates formative assessment techniques
- Instruction includes direct experience with natural phenomena
- Instruction is group/learner-centered
- Instruction provides opportunities and sufficient time for self-expression and communication
- Instruction models a passion for science

Status Quo
- Instruction is aligned with curricula that are inadequate
- Instruction is teacher-centered and didactic: (covering the material is equated with student learning)
- Instruction pays little attention to what students know and can do
- Instruction does not use formative assessment techniques
- Instruction is the same for all students; when students fail it is assumed to be their own fault
- Instruction raises significant equity issues

<u>Recommendations</u>
- **Provide** instructional models that:
  - are aligned with curriculum and instruction
  - are student-centered, and utilize current ideas about how students learn (by using what they know, can do, and have experienced to make sense of new ideas)
  - give students opportunities to explore different ideas and the reasoning that supports these ideas
- **Provide** professional development learning opportunities to help teachers implement new instructional models
- **Present** data and reasoned arguments that demonstrate shortcomings of current instructional practices

Assessment

<u>Summary</u>
Vision
- Assessments are aligned with curriculum and instruction
- Assessments are based on high quality, widely accepted standards

- Assessments comprise a full range of alternative methods to match different types of curricular and instructional goal
- Assessments include both formative and summative assessments
- Assessments reflect the full range of educational objectives, rather than focusing on knowledge items
- Assessments are integrated with instruction and do not distort teaching schedule (even for high stakes testing)

Status Quo

- Assessments are norm-referenced
- Assessments emphasize traditional select type assessments, e.g., multiple choice
- Assessments are not representative of full range of educational objectives
- Assessments emphasize summative assessments
- Assessments are poor assessments of student learning; do not fully reflect studentsÕ understandings and skills
- Assessments drive instruction when teachers teach to high stakes tests at the expense of student understanding.
- Assessments for accountability give inflated assessment of learning
- Assessments can exacerbate equity issues

Recommendations

- **Provide** assessment methods and instruments that:
  - are fair, equitable, authentic, and useful for all stakeholders
  - aligned with, and supportive of, innovative teaching and curriculum
  - are an integral part of instruction, rather than independent activities that reduce the time available for science teaching.
- **Provide** professional development learning opportunities to help teachers learn about and implement new assessment strategies
- **Present** data and reasoned arguments that demonstrate shortcomings of current assessment strategies

Science

Summary

Vision

- Science includes content, a body of knowledge
- Science includes inquiryÑa way of coming to know natural phenomenaÑthat is based on, but goes beyond, a body of knowledge

Status Quo

- School science is a fact-oriented body of knowledge; a set of formulae and definitions
- School science lacks the level of inquiry found in real-world research and development
- School science concentrates on esoteric content with few relationships to the world

Recommendations

- **Provide**:
  - aligned curricula, instructional models, and assessment methods that reflect all aspects of science
  - opportunities for students to do science in realistic settings
  - professional development learning opportunities to help teachers deepen their understanding of science and to learn about and implement all aspects of science
  - resources, school climate, administrative support

THE SCHOOL DISTRICT

Vision

Imagine a group of teachers who are attending a three-week summer institute whose purpose is to enhance teachersÕ content knowledge and instructional strategies in environmental sciences (Loucks-Horsley, Hewson, Love, & Stiles, 1998, p.7). It does so by using ÒscenariosÓ that immerse the teachers in problems that can only be solved by using investigative skills and integrating knowledge drawn from several disciplines. The environmental scenario poses the question: What is the impact on the environment when a farmer dumps various kinds of waste--diapers to left-over herbicide--into a ravine? After brainstorming about what they would need to know to address the problem--knowledge about soil, water, rock formations, decomposition rates of different kinds of materials, etc.--the teachers head off to study the dump site and its surroundings. Their geologist guide points out particular features of the rock structures and soil. A briefing book provides details of the local economy, notable industries, and patterns of irrigation. They also learn from a chemist about different methods of gathering and analyzing data about the area, particularly with respect to water and soil. They begin to formulate some ideas about possible outcomes of the dumping; this leads to more questions and further data gathering. Through discussions of their results with their experts, they come to understand the underlying scientific ideas.

Imagine a high school in which the science teachers have a common planning period to discuss their unified science curriculum (Newmann & Wehlage, 1995, p.38; Williams, forthcoming). The focus of their daily meeting changes as the school year progresses and different issues emerge: coordinating between sections of the freshman science course, planning how a new computer lab will be used, ensuring that common themes across different years are handled consistently, introducing more authentic assessment activities. Currently they are working on curriculum around a modeling theme: providing students with conceptual models for understanding scientific phenomena. The goal is that students will start with a model that explains some aspects of a phenomenon, e.g., the sun-moon-earth system, but that needs to be expanded and perhaps revised when other related phenomena are considered. During the summer, they had worked intensively with science educators from a local university in understanding the range of astronomical models for themselves. Now they (and their university colleagues) are grappling with the instructional implications of introducing this approach into their classes. Is it time well spent for students to develop a model that has initial appeal, but limited applicability? When, and how, should they intervene? What kinds of assessments can they use that are sensitive to the various aspects of doing science that their students are engaged in beyond acquiring scientific information? One teacher talks about what happened in his third-hour Science II section... (Passmore et al., 2001)

Imagine a group of school districts that has organized an academy for its principals (Murphy, 2001; Richard, 2001). By pooling resources the group is able to support a program that is both more intensive and more extensive than would otherwise have been possible. It consists of a summer workshop and monthly meetings throughout the school year. The focus of the academy is to help principals understand how to improve curriculum and instruction, particularly in relation to recently instituted state-wide student tests in science, mathematics, and other subjects. To this end, the principals study how to analyze their studentsÕ test data--provided by the stateÕs education department--and to use these analyses with their teachers in order to facilitate significant changes in approaches to teaching science and mathematics. At their monthly meetings, in a collegial, supportive environment, principals share with one another the successes and failures of the initiatives they have taken, and brainstorm solutions and different approaches. In participating in these principal academies, the principals are moving beyond the isolation of their responsibility for their individual schools. They are no longer only school managers, important as that may be. They are also becoming instructional leaders in facilitating the alignment of instruction, curriculum, and assessment to improve student learning.

These images illustrate different strategies for achieving professional development. These vary with respect to their format, e.g., summer workshops, monthly meetings, daily planning periods, and the nature of the activity, e.g., scientific inquiry, curriculum development. Strategies that support professional learning for science teachers include (Loucks-Horsley et al., 1998, pp.42-172):

- Immersion in inquiry into science or mathematics
- Immersion in the world of scientists and mathematicians
- Curriculum implementation
- Curriculum replacement units
- Curriculum development and adaptation
- Workshops, institutes, courses, and seminars
- Action research
- Case discussions
- Study groups
- Examining student work and student thinking and scoring assessments
- Coaching and mentoring
- Partnerships with scientists and mathematicians in business, industry, and universities
- Developing professional developers
- Technology for professional learning

Each of these strategies are described, exemplified, and commented on in terms of its underlying assumptions, key elements, and implementation requirements.

These images convey the message that opportunities for science teachersÕ professional learning need to serve various purposes (Loucks-Horsley et al., 1998, p.45).

- **Developing awareness**. Teachers need to develop an awareness that there are alternative approaches to the teaching of science that are worth considering.

Teachers can be so involved with their current practices and coping with the many challenges that arise that they have little time to pay attention to recent ideas. Once they become aware that there are different practices worth considering, they begin to ask questions about their own practices.

- **Building knowledge**. Any approach to science teaching is built on a foundation of knowledge about the science being taught, how this science is incorporated into curriculum materials and approaches, the ways in which students learn science, and instructional approaches that support studentsÕscience learning. Teachers need opportunities to learn and understand the knowledge that supports a different approach.
- **Translating into practice**. Knowing about a new approach is one thing; putting it into practice is entirely another matter. Teachers need to plan for different curricular and instructional approaches by translating the principles of these new approaches into the specific context of their students, resources, and other school constraints.
- **Practicing teaching**. Learning by doing is essential. While effective planning is a necessary prelude to actual teaching, students and classrooms are too complex to be modeled exactly in any plan, even if the plans are the product of translating an expanded knowledge base into the local context.
- **Reflection**. When teachers have time and inclination to look back at their teaching, particularly when it happens with the support and encouragement of sympathetic peers, they are able to identify what went well, and where they need to think through an activity more thoroughly. Doing so crystallizes what is learned from practice, thereby improving teaching in the future. (Calderhead & Gates, 1993; Clift, Houston, & Pugach, 1990; Hewson et al., 1999)

NCREL Teacher Colloquium
Master Ohio teachers believe that the following professional development opportunities would help teachers improve their performance:

- Continual professional development during the day, focusing on teacher knowledge and understanding of key ideas and how children learn
- Mentor or Òcritical friendÓprograms
- Time for collegial, collaborative discussion among peers
- Immersion in the learning process (e.g. Project Discovery)
- National Board certification.

(Otto et al., 2000, p.6)

Further, implicit in these images is the recognition that achieving these different purposes requires appropriate strategies (Brown & Smith, 1997; Loucks-Horsley et al., 1998, p.45). To illustrate, concentrated summer workshops are good for developing awareness and building knowledge of science content and related teaching approaches. Thus, if the focus is on immersion in the world of scientists, teachers will gain science knowledge; if the focus is on adapting curriculum, teachers will gain skills in translating into practice. Summer workshops are not, however, appropriate for achieving the purposes of practicing teaching and reflecting on practice. These are much better served by strategies that are used in parallel with normal teaching; strategies such as coaching, mentoring, case discussions, action research, or examining student work.

Another implication of these images is that all school professionals--administrators and teachers--need to be involved if the goal of enhanced student learning is to be achieved. While much national attention has been focused on teachers (e.g., (National Commission on Mathematics and Science Teaching for the 21st Century, 2000)--and rightly so--its effect will be significantly dissipated if the environment in which teachers work, and the people influencing this environment, do not change in corresponding ways. Classroom systems are only effective when they work in tandem with the school and district system of which they are subsystems (Newmann & Wehlage, 1995, p.41). One powerful way in which congruence of this nature can be attained and maintained is for school professionals to take on multiple roles, e.g., teachers as curriculum developers or peer mentors in addition to being classroom instructors, administrators as both instructional leaders and school managers. The reflective opportunities of examining one role from the standpoint of another can lead to major enhancements in the understanding of both roles.

University of Cincinnati Public Opinion Survey
Of those surveyed in Ohio, 97% agreed that it was important to implement professional development for science teachers. Respondents were closely divided between those who would be willing to spend more (45%) and those who would be prepared to spend the same (47%) to improve science education.
(Evaluation Services Center, 2001)

Another feature of these images is that when school professionals--administrators and teachers--develop, they do so along personal, social, and professional pathways that are interwoven with each other (Bell & Gilbert, 1996). They may start with the personal recognition that aspects of their practice are problematic, and realize socially that isolation from peers is also problematic. Professionally, they are prepared to try out new activities. A consequence of this is that they realize the need to deal personally with typical constraints of their work environment, e.g., the need to coordinate with colleagues or work within externally mandated guidelines. In grappling with these issues, they realize, socially, the value of collaborating with their colleagues, and, professionally, the need to develop a more coherent practice that goes beyond changes in individual activities. As these become embedded in their practice, school professionals, personally, increasingly feel empowered. As a result, they take the initiative, socially, of fostering collaborative ways of working, and professionally, of seeking out different opportunities for development.

These images of professional learning and practice in schools and school districts are grounded in reality, and supported by well documented, current practice. These practices are, however, not the *status quo*. It is more likely that you would encounter a different set of images were you to visit a representative set of schools and school districts.

Status Quo

Teaching science for most teachers is, professionally, an isolating experience. School schedules and teachersÕ expectations come together to create a culture that prizes individuality, resourcefulness, and independence. Teachers have few opportunities and little encouragement during their working day to interact with their colleagues. Their schedules require them to spend most of their time in their classrooms with their students. If other adults do come into their rooms, it is usually for administrative or evaluative purposes. So teachers come to expect that they will teach with their doors closed. Further, teachersÕ planning periods arenÕt necessarily scheduled at the same times as their science colleagues. Even if they are, after gathering resources or taking care of administrative duties, there is little time left to talk professionally to colleagues. Even if time was available for professional conversations, many science teachers would not see this as a priority. Talking about things that have gone well wonÕt endear you to your colleagues, while talking about problems that have arisen sound like weakness; you certainly wouldnÕt want your administrator to hear about them. Finally, colleagues are not always available: for many teachers in smaller schools, there may be no other science teacher in the building.

The opportunities for teachers to engage in significant professional development are limited (Committee on Science and Mathematics Teacher Preparation, 2001, p. 2). Those typically provided tend to be short, one-shot deals (Committee on Science and Mathematics Teacher Preparation, 2001, pp. 33-34). These come in forms such as in-service days, short workshops, and conferences. Local staff development personnel, college professors, and national speakers provide a range of information for teachers to take with them to incorporate into their normal practice. TeachersÕ experiences with these kinds of events is varied. In some cases, teachers hear something that either fits with their current practice, or solves a problem they are currently facing; putting it into practice in such a prepared environment is relatively straightforward. But more often than not, the influence of these sorts of events on a teacherÕs practice is negligible. This might be because teachers see little value in what they hear, viz., unwanted answers to unasked questions. But equally, it is likely that the difficulties of applying a new idea in the different circumstances of a teacherÕs practice have not been recognized and addressed. The assumption here is that if you hear something, you can do it. In other words, typical in-service events have little impact on most teachersÕ practice, and their influence in leading to significant changes in the fundamentals aspects of a teacherÕs practice is negligible.

In recent years, considerable resources have been provided by federal agencies for more extensive professional development opportunities for science teachers. These include summer workshops in which teachers spend one or more weeks immersed in various activities that might focus on science inquiry, curriculum development, student learning, etc. Many teachers have found these activities to be energizing, challenging them to reexamine fundamental beliefs they have about teaching, learning, and the nature of science. When teachers return to school for the next academic year, they try out new approaches that embody different forms of curriculum, instruction, and assessment, and make different demands on resources of time and equipment. Many teachers, however, find that there is little support from their colleagues and administrators (Committee on Science and Mathematics Teacher Preparation, 2001, p.33); when units donÕt work as they did in different circumstances during the summer, there is little help available. Under these conditions, most teachers find that they cannot sustain their innovative practices, and revert to their former methods. Without school support, student achievement scores are lower (Newmann & Wehlage, 1995, p.32).

To summarize: consider the influence of a prevailing culture in a districtÕs schools where administrators are primarily focused on school management, where teachers are professionally isolated with little time for professional development, reflection, and interaction with their colleagues, where in-service opportunities are usually provided in forms that seldom permit the possibility of significant change, and where teachers who are enthusiastic about innovative approaches to science teaching receive little support to put them into practice. The overall effect of these characteristics of current school and district systems--subsystems of the system of education in the state--is that these systems function to maintain the *status quo*.

A school district is a system of components--classrooms, schools, personnel, policies--that interact with each other. It includes many classrooms, each of which is itself a subsystem. The school district itself is a subsystem, a component, of the system of education in the state of Ohio. Recommendations for change, therefore, need to form a coherent set that applies to all components of the system and their interactions. These are summarized in terms of major school district attributes: professional development, school structure and climate, and resources. Some of these recommendations are internal to the subsystem of the district, and can be internally implemented. A number of them will, however, need to be implemented beyond the school district subsystem; these are considered further in the following section.

Professional Development

<u>Summary</u>

Vision

- Professional development achieves different purposes such as helping teachers to a) increase their disciplinary knowledge, b) adapt this knowledge to local contexts, c) put it into practice in their classrooms, d) align their curricular, instructional, and assessment approaches, and e) become life-long learners and reflective practitioners

- Professional development achieves these purposes by providing learning opportunities in different forms, such as courses, coaching and mentoring, and peer support groups
- Professional development is long-term and sustained
- Professional development provides models of good teaching
- Professional development is available during the school day as well as after hours and during school vacations
- Professional development provides access to mentors and Òcritical friendsÓ
- Professional development encourages teachers to pursue National Board certification

Status Quo

- In-service professional development is usually provided in short courses and workshops with little follow up
- In-service professional development is inadequately funded
- In-service professional development does not provide mentors for beginning teachers
- In-service professional development is information-centered, and not focused on what teachers want and need
- In-service professional development does not model good teaching
- In-service professional development reaches only a small proportion of teachers

<u>Recommendations</u>

- **Provide** professional development learning opportunities (Committee on Science and Mathematics Teacher Preparation, 2001, pp.6-13):
- for teachers, curriculum directors, and administrators to increase their capacity to plan and design effective curricula; to analyze and choose appropriate curriculum materials; and to align curriculum with instruction and assessment.
- for administrators to become academic and instructional leaders
- for administrators and teachers to become professional developers in schools
- **Provide** these opportunities in different forms, such as courses, coaching and mentoring, and peer support groups in order to serve different purposes, such as building knowledge, adapting this knowledge to local contexts, putting it into practice in their classrooms, and reflecting on these innovations (Loucks-Horsley et al., 1998, p.42).

School Structure & Culture

<u>Summary</u>

Vision

- Schools are collaborative learning organizations that include administrators and teachers
- Schools provide opportunities for teachers to interact frequently with their peers
- School administrators are academic and instructional leaders as well as school managers
- Administrators, parents, and the community support teachersÕcontinuing professional development

Status Quo

- In schools:
  - there is little systemic support for teachersÕon-going learning
  - there is inadequate time for professional development, reflection, and interaction with colleagues in school
  - structure and organization of the school day does not always promote inquiry learning or provide adequate time for reflection
  - time is rarely available for interpreting and reflecting on the results of assessments
  - administratorsÕprimary focus is on school management
  - there is little opportunity for teachers to take on leadership roles

Recommendations

- **Change** the professional culture of schools in ways that support science teachers' developing professionalism and the continuous improvement of their teaching (Committee on Science and Mathematics Teacher Preparation, 2001, p.39)
- **Provide** administrators with professional development to become academic and instructional leaders
- **Form** vertical teams of administrators, curriculum directors, and teachers within districts
- **Recognize** that teachers have expertise that is valuable in curriculum design
- **Encourage** teachers to participate in cross-district collaboration and networking and take on leadership roles
- **Work** with parents, school board members, and other community members to convince them of the necessity to provide high quality in-service professional development (Committee on Science and Mathematics Teacher Preparation, 2001), pp.6-13]
- **Provide** resources to support long-term, sustained professional development for teachers and administrators
- **Provide** time and resources for teachers to engage in detailed curriculum development

Curriculum Planning, Design, and Alignment

<u>Summary</u>

Vision

- Science and mathematics curricula are designed by teams of teachers and curriculum directors with:
  - capacity to carry out sophisticated curriculum analysis and design
  - access to experience, expertise, up-to-date research, and other resources concerning curriculum analysis and design
  - time to develop quality curricula that match external standards with local circumstances, and that are aligned with instruction and assessment across grade levels

Status Quo

- Science curricula:
  - have little coherency across grade levels
  - are driven by adopted text books that are inappropriately chosen
  - are determined with little teacher input
  - are not informed by appropriate curricular analysis
  - are politically influenced by various constituencies (e.g., battles over inclusion of evolution in biology curricula)

<u>Recommendations</u>

- **Recognize** that teachers have expertise that is valuable in curriculum design
- **Provide**:
  - professional development opportunities for teachers, curriculum directors, and administrators to increase their capacity to plan and design effective curricula; to analyze and choose appropriate curriculum materials; and to align curriculum with instruction and assessment
  - time and resources for teachers to engage in detailed curriculum development (e.g., lesson study)

THE STATE

At the state level, the systemic nature of education is clear to see. In response to perceived societal needs, policy makers and state-level administrators exert their leadership by setting policy for the system and its various entities, such as school districts and teacher education institutions: they set goals, establish guidelines, and provide resources for educational personnel throughout the state. In effect, they are sharing responsibility for achieving the stateÕs educational goals with school districts and teacher education institutions across the state. That, of course, is not the end of the matter. State personnel also require accountability of those with whom they share responsibility. Thus, they oversee the results emerging from the system, in order to monitor the success in achieving goals. In some cases, state personnel use results that emerge as a direct consequence of districtsÕ activities, such as student GPA distributions, course selections, etc. In other cases, they initiate particular types of activity, such as student and teacher testing, to provide information on system goals that would not otherwise be available. This account, while drastically oversimplified, highlights key features of the system: there are different entities within the system that have different functions and responsibilities, and they interact reciprocally with one another in different ways. Just because it is a system does not, however, mean that it automatically functions effectively, even if some components and their interactions are exemplary (Newmann & Wehlage, 1995, p.1).

The state has a range of responsibilities for education. These include, but are not limited to curriculum and assessment; school finance and accountability; school reform; students, families, and communities; superintendency; and the teaching profession (Ohio Department of Education, 2001). This document, however, focuses on a limited subset of these responsibilities.

Vision

Imagine a system of education for science in Ohio that has various components that work together in a supportive, coherent fashion. These include:

- High academic standards in science for all students, with detailed illustrations of how curriculum and instruction can be developed to embody these standards,
- Accountability measures that inspire public confidence and are fair to those being held accountable,
- A system of teacher education (with particular reference to science) to make the vision a reality.

An effective system of education sets common, demanding academic standards in science for all its students (Newmann & Wehlage, 1995, p. 41). In Ohio these standards should be comparable with national standards, mirror the best thinking of what is central to the disciplines, take into consideration the economic needs of the state, be relevant in the life and work of all Ohioans, and be interesting and accessible to all students. Putting academic standards into practice for all students requires more than simply specifying the standards and accountability measures. While this is necessary, it is not sufficient to determine what could or should happen in classrooms. Students who achieve any given standard may well have traveled along different instructional pathways. Which pathway a teacher chooses to use will depend on a variety of contextual characteristics such as the teacherÕs expertise and interests, and available resources in the school and community. Thus detailed illustrations of curriculum materials that embody some of the standards are needed. These are accompanied by outlines of instructional approaches for using these materials that provide curriculum directors and teachers with effective models for helping their students achieve these standards. These serve not only to inform schools about what these standards mean and different ways of achieving them, but also to guide them in developing their own, locally relevant instructional materials for other standards.

While the national debate on setting standards is of recent origin, historically, high academic standards, though not necessarily stated explicitly, have been in effect: some students in most schools have achieved excellence; these are the students who over the decades have helped Ohio and the nation achieve a position of leadership in the world in science and mathematics. Where there is a difference in opinion is whether **all** students should be held to meeting a common set of standards, since, historically, that has not been the expectation. In the dynamic world of the new millennium, however, this point of view needs re-examining. While not everyone will work in positions that include science or mathematics as an explicit requirement, the depth of science and mathematics literacy required, even for entry level positions, is steadily increasing. Difficult as this may be for many, OhioÕs future economic well-being depends critically on helping all its students meet common demanding standards of scientific literacy.

University of Cincinnati Public Opinion Survey
The importance of setting academic standards is fully recognized in Ohio: more than 92% of those surveyed supported standards.
While setting standards is generally accepted within Ohio, the question of how they should be set is less certain. Approximately equal numbers of those surveyed thought that standards should be set at local, state, or national levels, respectively. (Evaluation Services Center, 2001)

Ideally, there should be input into the setting of standards from different stakeholders. To be sure, the type of input will vary. A primary input into the process of choosing the content, format, and extent of standards comes from educators. These include those who have expertise in the content of science, and in curriculum and instruction, perhaps identified through professional organizations that focus on science education. Input should also come from those who put standards into practice in schools: teachers, curriculum directors, and administrators. Finally other interested stakeholdersÑeducational partnersÑshould have opportunities to respond to proposed standards.

An effective system of education in Ohio also includes a system of accountability measures that are coupled with accepted standards. Accountability measures need to meet different criteria to be effective. For educational partners, accountability measures need to inspire public confidence. They do so if they provide credible evidence that educators have discharged their responsibilities faithfully and effectively. For educators who are responsible for meeting the standards, accountability measures need to be valid and fair. They are valid if the information they provide can be used to make accurate inferences about student learning and system quality. They are fair if they are equitably administered for all, with adequate notice, opportunity to learn, chances to remediate, and lack of bias. In this case, those who are accountable believe that the measures serve to justify the trust that has been placed in them.

One purpose of coupling accountability measures with common academic standards for all students in all schools is to reduce inequities. It is common knowledge that, even within counties, as well as across the state, major differences currently exist between school districts with respect to academic achievement. By combining accountability with standards, the state creates a common set of expectations across the state for students and their parents, teachers, and administrators. While all parents want their children to be successful, what they regard as being successful is, in all likelihood, linked to their own educational experiences and current circumstances. In some school districts in the state, the expectations of most stakeholders are to a considerable extent already aligned with high academic standards. Consider districts in which parents and community members are knowledgeable about, and value, education, perhaps recognizing the central role it played in their own careers, and in which the community judges schools on the basis of their success in opening doors for further education of their students. The alignment of the publicÕs expectations with high academic standards, and accountability measures is a major factor in these districts achieving success. In other schools, however, community and societal pressures can create expectations of schools that may not include high academic achievement. If parents feel that the education system failed them, and has contributed little to their current circumstances, they are likely to have different expectations of their local schools. There may be little motivation to push schools to set high academic standards, as well as a lack of knowledge of how and why to do so. Under these circumstances, schools are far less likely to challenge students. Without externally mandated standards that are coupled with accountability measures, divergent expectations across the full range of OhioÕs schools are likely to maintain, if not exacerbate, current inequities in studentsÕ educational opportunities in science.

An effective system of education in Ohio also includes a system of teacher education that prepares and continuously supports K-12 teachers in science for the new millennium (Carter, 1990; Committee on Science and Mathematics Teacher Preparation, 2001; Feiman-Nemser & Remillard, 1995; Hewson et al., 1999; Northfield, Gunstone, & Erickson, 1996; Richardson, 1997). It recognizes that there should be a continuum of professional learning experiences throughout a teacherÕs career, seamlessly linking initial teacher certification to inservice professional development (Mundry, Spector, Stiles, & Loucks-Horsley, 1999)[Committee on Science and Mathematics Teacher Preparation, 2001 #1317, p.72). It does so by providing opportunities for prospective and practicing teachers to learn the different fields of knowledge in which expert teaching is rooted in ways that integrate them with each other and with classroom practice (Cochran & Jones, 1998). These fields include science content, educational foundations, and approaches to curriculum, instruction, and assessment (Anderson & Mitchener, 1994; Hewson, 1996; McDermott, 1990). These fields are taught in innovative ways that support the vision of science teaching detailed in the classroom section. Teacher education also provides opportunities for prospective and practicing teachers to learn how to put these approaches into practice in supportive, collegial environments that foster continuing personal, social, and professional teacher development (Bell & Gilbert, 1994; Gold, 1996). It also provides opportunities for integrating theory with practice through continual, reciprocal dialogues that highlight their mutual interactions. These learning opportunities come in a variety of different forms; not only in courses and workshops, but also through internships, immersion experiences, study groups, mentored relationships, and so on. Further, these learning opportunities occur not only in pre-service programs that provide initial teacher certification, but also throughout teachersÕ professional lives (Kagan, 1992; Loucks-Horsley et al., 1998).

NCREL Teacher Colloquium Highlight
Master Ohio teachers believe that pre-service teacher education should:

- Increase the focus of teacher preparation programs to provide new teachers with a repertoire of techniques and a range of strategies for dealing with curriculum, pedagogy, assessment, and school context.
- Improve preparation of new teachers to run their own classrooms with diverse groups of children.
- Coordinate teacher preparation programs with mentoring programs and staff development by colleges, school districts, and unions.
- Teach practical teaching applications and techniques to preservice teachers.
- Provide more exposure to rigorous disciplinary courses in the content areas.

(Otto et al., 2000, p.6-7)

Teachers who have been educated in this system regard themselves as life long learners (Committee on Science and Mathematics Teacher Preparation, 2001, p. 7; Floden, Gallagher, Wong, & Roseman, 1995, p.45). They are knowledgeable about science, and about the foundational principles of education in Ohio and the nation. They are knowledgeable about OhioÕs high academic standards and detailed curriculum models that exemplify them. They can use these standards and models to produce their own locally appropriate curriculum and instruction. They can teach science to all students in the ways detailed in the vision of OhioÕs classrooms. They also have the motivation and skills to continue improving their practice throughout their professional careers.

Status Quo

Translating the overarching goals of a reform into practice is a complicated process. The intent of any reform initiative is that there should be fidelity between the goals of the reform, the forms and strategies with which the reform is implemented, and the outcomes of the implementation. A tendency, inherent in all complex processes, is that there are shifts along every step of the way that can compromise the fidelity of the reform. In cases where the shifts are major, the outcomes of the reform may bear little resemblance to the ideals that led to its establishment. At every point along the way, practitioners understandably attend primarily to their local priorities, and secondarily to overall perspectives. They are likely to assume that the resourcesÑcurriculum and assessment materialsÑthat they use, are faithfully aligned with the corresponding standards. If there is no person or group whose primary responsibility is to maintain the fidelity of the reform, these may be faulty assumptions, leading to a compromised reform initiative.

> The academic content standards will provide a set of clear and rigorous expectations for all students. Students will need to learn more and do complex work, at each grade level, as they progress through school. The new academic content standards will provide clarity to Ohio teachers of what content and skills should be taught at each grade-level. However, how the material will be taught local school and district decision.
> (Ohio Department of Education, 2001)

The state of Ohio attends to the different features of a system of education. There are sets of academic content standards for science that are based on national standards documents. There are accountability measures for students, teachers, and school districts. There is state oversight of teacher licensing, and of the many higher education institutions that produce teachers of science (Ohio Department of Education, 2001). In the state of Ohio, standards are embodied in ODEÕs curriculum models that were designed to be used in conjunction with national standards documents such as those produced by the National Research Council (National Research Council, 1996) and the National Council of Teachers of Mathematics (National Council of Teachers of Mathematics, 2000). They have been favorably rated in comparison with those of other states (Finn & Petrilli, 2000; Glidden, Masur, & Snowden, 1999). Some of the best science and mathematics teachers in Ohio, however, think that these models emphasize process rather than content, and, along with the Proficiency Tests, drive schools and teachers to teach a curriculum that is superficial because of the large amount of content included (Otto, van der Ploeg, & Blakeslee, 2000, p.8). Academic content standards in science are currently being revised (Ohio Department of Education, 2001).

Science teachers in Ohio use a variety of different resources in deciding how they will teach. These include national standards documents, ODEÕs proficiency test guidelines, curriculum models, school and district curriculum guides, and textbooks. Of these resources, teachers use textbooks more frequently than any other (van der Ploeg, 2000, p.29). There are several ways in which the overall purpose of a reform can be distorted by textbooks. The need to seek wider audiences can lead publishers to include more content than a school districtÕs curriculum might require. The presence of additional material can suggest to teachers that their curriculum ought to be expanded, with the outcome that they include more topics, each handled in less detail and depth than previously. A publisher may also believe that a complete package will be more marketable nationally. A consequence is likely to be that teachers are less likely to develop their own units. Finally, publishers seek to create unique features that will help their product stand out in a crowded market. Thus when different school districts adopt different textbook series, different emphases can occur across districts. Yet analyses of prominent textbook series for conformity with current standards have shown that no middle grade science text received at least a satisfactory rating and high school biology textbooks had serious shortcomings (American Association for the Advancement of Science, 1999, 2000).

University of Cincinnati Public Opinion Survey
Of those surveyed, 91% believed that all teachers should be tested periodically to determine their proficiency in science. The majority of respondents (85%) believed that OhioÕs science proficiency tests should be comparable to other state and national tests. However, only 49% believed that proficiency tests were a fair measure of student learning.
(Evaluation Services Center, 2001)

Ohio has in recent years adopted several statewide accountability measures. The most prominent of these are the Ohio Proficiency Tests (OPT) that are administered to all students at the 4^{th}, 6^{th}, 9^{th}, and 12^{th} grades, Òto test their knowledge and skills in core subject areas,Ó including science. School district report cards are another prominent accountability measure, based in large part on OPT outcomes (Ohio Department of Education, 2001). While the content of science proficiency tests has been favorably reviewed, there are grounds for questioning both the fairness and the validity of the implementation of OhioÕs proficiency testing policy, in part as a result of its unintended consequences. To illustrate one concern, at one urban middle school the percentage of students passing the 6^{th} grade science remained under 10% for several years, in contrast to the stateÕs performance standard of 75%. In response to this dramatic indication of ongoing failure, the school regularly spent the weeks prior to proficiency testing in intensive training efforts (Hewson & Davies, 1998). Whether or not this had educative value, it represented a massive distortion of the schoolÕs intended curriculum in science and other core subjects. Another concern is the tendency to concentrate on high stakes tests to the exclusion of other forms of assessment, even though educators and testing companies themselves stress the need for multiple forms of assessment. This concern is compounded by the need for testing companies to produce accurate, timely results. Recent reports have documented errors in high stakes test results that have had severe consequences for large numbers of students and administrators (Henriques & Steinberg, 2001; Steinberg & Henriques, 2001).

Teacher education in Ohio, as elsewhere, occurs in two phases. The first phase is pre-service teacher education. This is provided by institutions of higher education (IHEÕs) across the state with the primary purpose of preparing prospective teachers for licensure. The second phase is in-service teacher education (or professional development). This is provided by IHEÕs, school districts, and other organizations for a variety of purposes, such as supporting recently licensed teachers, introducing different curricular, instructional, and assessment approaches, and updating teachersÕ competencies. The lack of continuity between the two phases is a major concern (Committee on Science and Mathematics Teacher Preparation, 2001, p.109). On the one hand, this is understandable. Licensure in pre-service teacher education introduces a range of requirements that can only be fulfilled by an extensive, complex program that for many students involves full-time study, whereas in-service teacher education can focus on particular topics that can be addressed in single sessions or by intermittent, part-time attendance. The lack of continuity is also understandable, given the differences between institutions providing teacher education in the two phases. On the other hand, the discontinuity between the two phases is regrettable, given that they share a common purpose of educating teachers. If the goal is that teachers be life-long learners, the first phase needs to be a preparation for the start of a journey rather than an endpoint, a terminal qualification.

While pre-service teacher education has always met the goal of producing graduates who can be licensed to teach, it has very largely proved to be a weak intervention, with respect to its influence on practice. This is due to several different factors. Science content courses largely provide inappropriate models of content as a body of unquestionable knowledge, and of instruction as presentation of this information (Committee on Science and Mathematics Teacher Preparation, 2001, pp.55-65; Kuerbis & Micikas, 1996; Lemberger, Hewson, & Park, 1999). Courses in educational foundations often appear to be far removed from the realities of classroom and school. Integrating the various components of a certification program is a task that is largely left to its students. There is little dialog between education theories and the practice that student teachers experience. New teachers continue to find that their greatest learning happens during their first year of teaching when they are least able to be thoughtful about what they are learning. What they learn under these circumstances may help them survive in the short term, but may well be counter-productive in the long term.

In-service teacher education has also, for the most part, been ineffectual. One very common model is that of staff development days, largely provided by school districts. Most teachers regard these largely as a waste of time. Criticisms are that they are on topics that are seldom relevant, they do not model good teaching, and they are of insufficient duration to have any lasting effect. Another common model is that of summer workshops; significant resources, particularly over the past decade, have been allocated to these activities. The intensive experiences that these provide are able to excite teachers about the possibilities inherent in different approaches to science teaching. Yet all too often, when teachers return to their schools, there is insufficient time in their day, and little support from their peers, for the hard work of transforming good ideas into a workable practice. As such, they revert to their familiar forms of teaching.

Standards

<u>Summary</u>

Vision

- Standards are of high academic achievement
- Standards apply to all students
- Standards are comparable to national standards
- Standards mirror best disciplinary thinking
- Standards are relevant, interesting, and accessible to students
- Standards are set with input from all stakeholders
- Standards are supported by detailed models of curriculum & instruction

Status Quo

- Standards in Ohio are embodied in ODE's curriculum models.
- ODE models:
  - emphasize process at the expense of content
  - drive schools and teachers to teach a curriculum that is "a mile wide and an inch deep"
- *De facto* standards across school districts:
  - are implicit in textbook selections
  - vary considerably

<u>Recommendations</u>

- Establish uniform national standards that encourage depth of understanding rather than breadth of coverage.
- Provide detailed models that illustrate how standards can be transformed into effective curriculum & instruction.
- Monitor fidelity of reform across goals, implementation, and outcomes.

Accountability

<u>Summary</u>

Vision
- Accountability measures inspire public confidence
- Accountability measures are valid representations of standards
- Accountability measures are fair to those held accountable
- Accountability measures serve to reduce inequities

Status Quo
- Accountability measures in Ohio include:
  - student proficiency testing
  - school & district report card
- Proficiency tests:
  - are regarded as unfair by some
  - can distort schools' curriculum & instruction

<u>Recommendations</u>
- Combine student assessments from various sources, including external high-stakes tests, school-based tests, and continuous assessments
- Provide resources to support accountability mandates

Teacher Education

<u>Summary</u>

Vision
- Pre-service teacher education:
  - includes sophisticated curricular & pedagogical knowledge in content domains
  - includes psychological and sociological foundations of education
  - integrates theory & practice
  - provides learning experiences in different forms
  - helps teachers become life long learners
  - prepares teachers for in-service professional development

- Teacher education:
  - is a continuum of programs
  - seamlessly connects pre-service and in-service learning opportunities
  - fosters career-long learning
  - focuses on both content knowledge and pedagogical approaches
  - provides teachers with opportunities both to grow individually and to contribute to the profession

Status Quo

- Pre-service teacher education:
  - includes content courses that inappropriately model content, instruction
  - has a fragmented curriculum
  - does not connect with in-service professional development
  - does not adequately prepare teachers
  - has little influence on practice

<u>Recommendations</u>

- **Develop** certification programs for prospective teachers that:
  - integrate science content, educational foundations, methodology, and school experience
  - prepare teachers to become career-long learners
- **Develop** college level content courses that model innovative content and instruction for prospective and practicing teachers
- **Develop** partnership relationships between school districts and tertiary institutions to provide professional learning opportunities for practicing and prospective teachers
- **Develop** content courses that model innovative content, instruction.

CONCLUSION

The system of science education in the state of Ohio needs to be transformed if it is to meet the demands of the 21st century. To be successful, the transformation must be a systemic enterprise that builds on the strengths and accomplishments of the past, while addressing the new demands of a rapidly changing world. Piece-by-piece tinkering, while much easier to accomplish, is not the answer. The transformation needs to be driven by an overarching, comprehensive vision of what is both possible and desirable, based on accepted principles of learning, teaching, and leadership. Achieving a vision that makes sense for the system requires that all stakeholders of the systemÑstudents, educators (teachers; administrators at school, district, and state levels; educators of teachers and administrators; and members of professional organizations) and educational partners (parents, community members, people in business and industry; and policy makers)Ñneed to be involved, as they commit themselves to the common vision in ways that make sense for themselves.

The vision includes personnel involved at all levels of the systemÑclassroom, school, and state. Thus:

- **Students** must become active learners rather than passive recipients of inert school knowledge.
- **Teachers** must become activated professionals whose creativity and wealth of experience are utilized to transform education (curriculum content and instructional methods) rather than serving as puppets who are expected passively to receive instructions from ÒaboveÓ and unimaginatively teach inert knowledge to passive students.
- **System administrators** must be transformed to become academic leaders who promote curriculum and instructional innovation and encourage superintendents and principals into active supportive roles rather than being top-down authority figures who are perceived as remote administrative managers.

These transformations in people and the roles they play need to be supported by other changes. These include:

- **Knowledge**. Seeing that knowledge is meaningful, recognizing that it is changing, and knowing how it develops and changes in a process of inquiry is at least as important as knowing what is currently accepted as facts, theories, and principles. Knowledge should no longer be regarded as inert and untouchable, and simply passed on from scientists through curriculum developers and teachers to students.
- **Learning Environments**. Top-down, one-way, remote-control models of authority in which participants in the system are isolated from each other are no longer effective in todayÕs schools. They need to give way to environments in which people collaborate with one another in professionally heterogeneous communities that foster mutual support and respect. Examples of heterogeneous communities include classrooms (students and teachers work together); schools (teachers and principals

collaborate); and communities (educators, parents, and community members develop common goals).
- **Accountability**. Methods of assessment of students, teachers, schools, and systems need to be expanded from final external evaluations of competency, to include methods that provide ongoing feedback to participants that they use for continuous improvement of their performance.

Detailed actions that are needed to bring about these transformations have been stated as recommendations in the body of this report. In general , these include the following:
- Spell out the vision for all stakeholders: students, educators, and educational partners.
- Provide case examples of how aspects of the vision have been realized. Many examples are contained in National Standards documents.
- Develop mechanisms through which the vision can be presented, discussed, restructured, accepted, and implemented. This means establishing various venues and structures that institute and support collaboration. To illustrate:
  - Form consortia of school districts through which superintendents, principals, and teachers form supportive learning communities.
  - Foster collaboration amongst teachers through timetable adjustments that allow teachers to meet regularly, share their expertise, and grow professionally.
- Disseminate these mechanisms to all appropriate stakeholders throughout the Ohio educational system.

REFERENCES

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82*(4), 417-436.

American Association for the Advancement of Science. (1999). *Heavy books light on learning*. Available: http://www.project2061.org/newsinfo/press/rl092899.htm.

American Association for the Advancement of Science. (2000). *Big biology books fail to convey big ideas*. Available: http://www.project2061.org/newsinfo/press/rl000627.htm.

American Institutes for Research. (2001). *An educators' guide to schoolwide reform*. Available: http://www.aasa.org/reform/.

Anderson, R. D., & Mitchener, C. P. (1994). Research on science teacher education. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 3-44). New York, NY: Macmillan.

Beeth, M. E., & Hewson, P. W. (1998). Learning Goals in an Exemplary Science Teacher's Practice: Cognitive and Social Factors in Teaching for Conceptual Change. *Science Education, 83*(6), 738-760.

Bell, B., & Gilbert, J. (1996). *Teacher Development: A model from science education*. London: Falmer Press.

Bell, B. F., & Gilbert, J. (1994). Teacher development as personal, professional and social development. *Teaching and Teacher Education, 10*(5), 483-497.

Brown, C. A., & Smith, M. S. (1997). Supporting the development of mathematical pedagogy. *The Mathematics Teacher, 90*(2), 138-143.

Calderhead, J., & Gates, P. (1993). *Conceptualizing reflection in teacher development*. Bristol, PA: The Falmer Press.

Carlsen, W. (1991). Effects of New Biology Teachers' Subject-Matter Knowledge on Curricular Planning. *Science Education, 75*(6), 631-647.

Carter, K. (1990). Teachers' knowledge and learning to teach. In W. R. Houston & M. Haberman & J. Sikula (Eds.), *Handbook of Research on Teacher Education* (pp. 291-310). New York: Macmillan.

Cartier, J. L., & Stewart, J. (2000). Teaching the nature of inquiry: Further developments in a high school genetics curriculum. *Science and Education, 9*, 247-267.

Clift, R. T., Houston, W. R., & Pugach, M. C. (1990). *Encouraging reflective practice in education: an analysis of issues and programs*. New York, NY: Teachers College Press.

Cobb, P., Wood, T., & Yackel, E. (1991). Analogies from the philosophy and sociology of science for understanding classroom life. *Science Education, 75*(1), 23-44.

Cochran, K. F., & Jones, L. L. (1998). The subject matter knowledge of preservice science teachers. In B. J. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education* (pp. 707-718). Dordrecht, Netherlands: Kluwer.

Committee on Science and Mathematics Teacher Preparation. (2001). *Educating teachers of science, mathematics, and technology*. Washington, DC: National Academy Press.

Duit, R., Treagust, D. F., & Mansfield, H. (1996). Investigating student understanding as a prerequisite to improving teaching and learning in science and mathematics. In D. F. Treagust & R. Duit & B. J. Fraser (Eds.), *Improving teaching and learning in science and mathematics* (pp. 17-31). New York, NY: Teachers College Press.

Duschl, R. (2000). Making the nature of science explicit: The contribution of research. In R. Millar & J. Leach & J. Osborne (Eds.), *Improving Science Education* (pp. 187-206). Buckingham, UK: Open University Press.

Evaluation Services Center. (2001). *Assessing public opinion and awareness of Ohio's education system in mathematics and science*. Cincinnati, OH: College of Education, University of Cincinnati.

Feiman-Nemser, S., & Remillard, J. (1995). Learning to teach. In F. B. Murray (Ed.), *The Teacher Educator's Handbook: Building a knowledge base for the preparation of teachers*. San Francisco, CA: Jossey-Bass.

Fenstermacher, G. D. (1986). Philosophy of research on teaching: Three aspects. In M. C. Wittrock (Ed.), *Handbook of Research on Teaching* (3rd ed., pp. 37-49). New York: Macmillan.

Finn, C. E., & Petrilli, M. J. (2000). *The state of state standards 2000*. Thomas B. Fordham Foundation. Available: www.edexcellence.net/library/soss2000.

Floden, R., Gallagher, J., Wong, D., & Roseman, J. E. (1995). *Project 2061 blueprint for teacher education.* Paper presented at the Annual meeting, American Educational Research Association, San Francisco, CA.

Fraser, B. J. (1998). Science learning environments: Assessment, effects and determinants. In B. J. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education* (pp. 527-564). Dordrecht, Netherlands: Kluwer.

Glidden, H., Masur, N. B., & Snowden, J. B. (1999). *Making Standards Matter 1999*. American Federation of Teachers. Available: www.aft.org/edissues/standards99/index.htm.

Gold, Y. (1996). Beginning teacher support: Attrition, mentoring, and induction. In J. Sikula & T. J. Buttery & E. Guyton (Eds.), *Handbook of research on teacher education* (Second ed., pp. 548-594). New York, NY: Macmillan.

Gunstone, R. F. (1994). The Importance of Specific Science Content in the Enhancement of Metacognition. In P. Fensham & R. Gunstone & R. White (Eds.), *The Content of Science: A Constructivist Approach to its Teaching and Learning* (pp. 131-146). Washington, D.C.: The Falmer Press.

Harrison, A. G., Grayson, D. J., & Treagust, D. F. (1999). Investigating a grade 11 student's evolving conceptions of heat and temperature. *Journal of Research in Science Teaching, 36*(1), 55-87.

Hashweh, M. Z. (1987). Effects of subject matter knowledge on the teaching of biology and physics. *Teaching and Teacher Education, 3*(2), 109-121.

Henriques, D. B., & Steinberg, J. (2001, May 20). Right answer, wrong score: Test flaws take toll*. New York Times,* pp. 1, 22-23.

Hershberg, T. (2000). Long-term skills for quick-turn tech. *Government Technology, 13*(7), 32-37.

Hestenes, D. (2001). *Modeling instruction in high school physics*. Available: http://modeling.asu.edu/modeling-HS.html.

Hewson, P. W. (1996). Professional development of science and mathematics teachers: The pre-service curriculum. In C. Stoll & L. de Feiter & H. Vonk & J. van den Akker (Eds.), *Improving science and mathematics teaching in Southern Africa: Effectiveness of interventions* (pp. 22-30). Amsterdam: VU University Press.

Hewson, P. W., Beeth, M. E., & Thorley, N. R. (1998). Teaching for conceptual change. In K. G. Tobin & B. J. Fraser (Eds.), *International Handbook of Science Education* (pp. 199-218). Dordrecht, Netherlands: Kluwer.

Hewson, P. W., & Davies, D. (1998). *"How much is too much?": A Case Study of Urban Middle School.* Paper presented at the Annual Meeting, American Educational Research Association, Montreal, Canada.

Hewson, P. W., & Hewson, M. G. A. B. (1988). An appropriate conception of teaching science: A view from studies of science learning. *Science Education, 72*(5), 597-614.

Hewson, P. W., & Lemberger, J. (2000). Status as the hallmark of conceptual learning. In R. Millar & J. Leach & J. Osborne (Eds.), *Improving science education: The contribution of research* (pp. 110-125). Buckingham, UK: Open University Press.

Hewson, P. W., Tabachnick, B. R., Zeichner, K. M., Blomker, K. B., Meyer, H., Lemberger, J., Marion, R., Park, H.-j., & Toolin, R. (1999). Educating prospective teachers of biology: Introduction and research methods. *Science Education, 83*(3), 247-273.

Hewson, P. W., & Thorley, N. R. (1989). The conditions of conceptual change in the classroom. *International Journal of Science Education, 11*(5), 541-553.

Hirst, P. H. (1971). What is teaching? *Journal of Curriculum Studies, 3*(1), 5-18.

Johnson, S. K., & Stewart, J. (1990). Using philosophy of science in curriculum development: An example from high school genetics. *International Journal of Science Education, 12*(3), 297-307.

Kagan, D. M. (1992). Professional growth among preservice and beginning teachers. *Review of Educational Research, 62*(2), 129-169.

Kelly, M. K., & Kahle, J. B. (2000, April). *Science education reform and school-level reform efforts in one urban middle school.* Paper presented at the Annual Meeting, National Association for Research in Science Teaching, New Orleans, LA.

Klaassen, C. W. J. M., & Lijnse, P. L. (1996). Interpreting students' and teachers' discourse in science classes: An underestimated problem? *Journal of Research in Science Teaching, 33*(2), 115-134.

Kuerbis, P. J., & Micikas, L. B. (1996). Teacher preparation in light of standards-based reform, *National standards and the science curriculum: Challenges, opportunities, and recommendations* (pp. 125-134). Dubuque, IA: Kendall-Hunt.

Lemberger, J., Hewson, P. W., & Park, H.-j. (1999). Relationships between prospective secondary teachers' classroom practice and their conceptions of biology and of teaching science. *Science Education, 83*(3), 347-371.

Loucks-Horsley, S., Hewson, P. W., Love, N., & Stiles, K. E. (1998). *Designing Professional Development for Teachers of Science and Mathematics Education*. Thousand Oaks, CA: Corwin Press.

McDermott, L. C. (1990). A perspective on teacher preparation in physics and other sciences: The need for special science courses for teachers. *American Journal of Physics, 58*(8), 734-742.

Metz, K. E. (1998). Scientific inquiry within reach of young children. In B. J. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education* (pp. 81-96). Dordrecht, Netherlands: Kluwer.

Mundry, S., Spector, B., Stiles, K., & Loucks-Horsley, S. (1999). *Working toward a continuum of professional learning experiences for teachers of science and mathematics*. Madison, WI: National Institute for Science Education, University of Wisconsin-Madison.

Murphy, J. (2001). *Ohio Principals Leadership Academy*. Available: www.ohioprincipals.org/.

National Center for Education Statistics. (1997). *1993-1994 Schools and Staffing Survey*. Washington, DC: U.S. Department of Education.

National Commission on Mathematics and Science Teaching for the 21st Century. (2000). *Before It'sToo Late*. Washington, DC: U.S. Department of Education.

National Council of Teachers of Mathematics. (2000). *Principles and Standards for School Mathematics*. Reston, VA: Author.

National Research Council. (1996). *National Science Education Standards*. Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the National Science Education Standards: A guide for teaching and learning*. Washington, DC: National Academy Press.

Newmann, F. M., & Wehlage, G. G. (1995). *Successful school restructuring*. Madison, WI: University of Wisconsin-Madison.

Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education, 21*(5), 553-576.

Nobel Foundation. (2001). *Nobel Prizes in Physics, Chemistry, and Medicine*. Available: www.nobel.se.

Northfield, J., Gunstone, R. F., & Erickson, G. (1996). A constructivist perspective on science teacher education. In D. F. Treagust & R. Duit & B. J. Fraser (Eds.), *Improving teaching and learning in science and mathematics* (pp. 201-211). New York, NY: Teachers College Press.

Ohio Department of Education. (2001). Available: www.ode.state.oh.us.

Otto, C., van der Ploeg, A., & Blakeslee, T. (2000). *Common Problems, Common Goals. The OMSC Teacher Colloquium: An interpretive synthesis*. Naperville, IL: NCREL.

Passmore, C. M., Cartier, J. L., & Barton, A. M. (2001). *Instructional practices that support inquiry-based student learning.* Paper presented at the Annual Meeting, National Association for Research n Science Teaching, St. Louis, MO.

Richard, A. (2001, May 23). Growth of Academies highlights new thinking about leadership. *Education Week, 20,* 1.

Richardson, V. (1997). *Constructivist approaches to teacher education*. Thousand Oaks, CA: Corwin Press.

Roberts, T. (2001). *Paideia Active Learning*. National Paideia Center. Available: http://www.paideia.org.

Schwab, J. J. (1962). The teaching of science inquiry. In J. J. Schwab & P. F. Brandwein (Eds.), *The teaching of science*. Cambridge, MA: Harvard University Press.

Scott, P. H., Asoko, H. M., & Driver, R. H. (1992). Teaching for conceptual change: A review of strategies. In R. Duit & F. Goldberg & H. Niedderer (Eds.), *Research in physics learning: Theoretical issues and empirical studies* (pp. 310-329). Kiel, Germany: IPN.

Smith, C. L., Maclin, D., Houghton, C., & Hennessey, M. G. (2000). Sixth-grade students' epistemologies of science: The impact of school science experiences on epistemological development. *Cognition and Instruction, 18*(3), 349-422.

Smith, M. S., & O'Day, J. (1993). Systemic reform and educational opportunity. In S. H. Fuhrman (Ed.), *Designing coherent policy*. San Francisco, CA: Jossey-Bass.

Steinberg, J., & Henriques, D. B. (2001, May 21). When a test fails the schools, careers and reputations suffer*.* *New York Times,* pp. 1, 10-11.

Thorley, N. R., & Woods, R. K. (1997). Case studies of students' learning as action research on conceptual change teaching. *International Journal of Science Education, 19*(2), 229-245.

Tytler, R. (1998). The nature of students' informal science conceptions. *International Journal of Science Education, 20*(8), 901-927.

U.S. Commission on National Security/21st Century. (2001). *Road Map for National Security: Imperative for Change*. Washington, DC.

U.S. Department of Education. (2001). *Exemplary and promising science programs*. Available: www.ed.gov/offices/OERI/ORAD/KAD/expert_panel/.

van der Ploeg, A. J. (2000). *K-12 Science in Ohio: What districts intend to teach, what teachers teach*. Oak Brook, IL: NCREL.

van Zee, E., & Minstrell, J. (1997). Reflective discourse: Developing shared understandings in a physics classroom. *International Journal of Science Education, 19*(2), 209-228.

Wells, M., Hestenes, D., & Swackhamer, G. (1995). A modeling method for high school physics instruction. *American Journal of Physics, 63*(7), 606-619.

Williams, T. (forthcoming). Designed changes. In A. Gamoran & C. W. Anderson & P. A. Quiroz & W. G. Secada & M. S. Gabella & T. Williams & S. Ashmann (Eds.), *Capacity for change: How districts and schools can support teaching for understanding in mathematics and science*. New York, NY: Teachers College Press.

Yahya, R. (1999). *A modeling approach in high school physics.* Unpublished Masters' thesis, University of Wisconsin-Madison, Madison, WI.