CHAPTER 7

Making It Happen

"Although the school is the central institution for public education, all parts of the extended system have a responsibility for improving science literacy… Only when most individuals and organizations share a common vision can we expect true excellence in science education to be achieved."

NSES, P. 8

Chapter 7

Systemic Reform

The *Minnesota Science Framework* describes a commitment to the vision of scientific literacy for all students. Such literacy includes being able to use scientific information to make sense of events in daily life, thoughtfully engage in discussion about issues of science and technology, and to be able to use science as a basis for taking action, scientific habits of mind in the workplace, and personal fulfillment. The vision for K-12 science education is characterized by two main features: using scientific inquiry in learning science concepts and processes, and an expanded view of science concepts, including having experiences in and understanding technology, science in personal and social perspectives, and the history and nature of science, as well as the traditional concepts in physical, life, and earth/space science.

" For systemic change to occur, all aspects of the system must move forward. A physician doesn't say, 'Well, I guess I won't worry too much about that heart problem. The rest of the body seems fine.'... By nurturing all aspects of the education system, we can bring about the systemic change that will transform education."

Anderson, 1993

Past attempts at school reform focused on only one or two parts of the system ("fix the curriculum," "change school structure") and in many cases involved finger-pointing and looking for blame. The current reform effort is more systemic because it acknowledges that improving education is a system-wide issue and that everyone must be involved. While teachers are central to achieving the vision called for by the *Minnesota Science Framework*, this new vision of an appropriate science education for all learners cannot be realized by teachers alone. Systemic reform requires the support and involvement of everyone who influences science education, including administrators, teacher educators, curriculum designers, local school boards, state departments of education, the federal government, students, parents, scientists and engineers, business people, legislators, other public officials, and other community members.

The term systemic reform means different things to different people. Politicians advocate for accountability and quality assurance, particularly as measured by standard test scores. Educators speak about vision, about what students should know and be able to do. To those with a systems orientation, the term stresses systems ideas such as the dynamic interaction among the various components of the educational system, the various boundaries, inputs and outputs, feedback, and relationships with the idea that these elements must be addressed in a comprehensive and coherent fashion. To others, especially those interested in developing the capacity of organizations to manage complex organizational reform for continuous improvements and to cope with change, emphasis is placed on schools as "learning organizations." This requires the active involvement of a variety of constituencies from the local to the national.

The *National Science Education Standards (*NSES) are explicit in their call for substantive rather than superficial changes in all components of the system—content, teaching, assessment, professional development, school and district programs, and other elements of the system. These are the same changes that the Minnesota Graduation Standards call for. Alongside standards for content, teaching, and assessment, the NSES provide three support standards: for professional development, for programs, and for systems.

The system standards are criteria for judging the performance of the overall science education system on a state or local basis. True systemic reform involves changes in each of the components of the system, and these changes must be made system-wide, that is, throughout the entire district, state, and nation. They include seven areas:

- Policies for science education that are consistent with the NSES teaching, professional development, assessment, content, and program standards.
- Coordinated science education policies within and across agencies, institutions, and organizations.
- Policies that provide sufficient time for making the changes called for.
- Policies supported with resources.
- Science education policies that are equitable.
- Examination of policies for potential unintended effects.
- The responsibility of all individuals in making changes consistent with the vision.

We Believe

Beliefs about science education that underlie this vision for science education and the systemic issues that are associated with that vision are described in Chapter One. They are the foundation for the Minnesota Science Framework and are consistent with both national standards and the Minnesota Graduation Standards and are worth repeating here. They serve as the basis for curriculum, instruction, and assessment; for designing comprehensive professional development programs; and for developing science programs.

These beliefs are:

A. That *all* students should be provided the opportunity to learn rigorous science.

B. That standards-based education and the *National Science Education Standards* can contribute to building capacity to improve curriculum, instruction, and assessment in Minnesota's K-12 schools.

C. That learning science is an active process.

D. That teachers are central to achieving excellence in science education.

E. That everyone has a role in improving and sustaining quality science education.

The reform embodied in the *Minnesota Science Framework* is encompassing and goes beyond teachers, although in the words of Schifter and Fosnot (1993), "it is [teachers] who will invent the practice that realizes the vision." A key question remains, however. How do we engage a wider community in developing and enacting reform in order to move this ambitious reform agenda forward?

Standards-Based Reform

'Standards' is a term that is laden with emotional and political overtones. One of the reasons for so much confusion and misunderstanding is that the word *standard* has three meanings that are frequently used interchangeably. The first definition of standards is that of a banner used as a symbol for a rallying point. These were common in battle in medieval times and are also seen with tour groups at Disneyworld. Standards can also be a given set of specifications that all parts of a system adhere to. Examples of this are the QWERTY key board and the use of red, green, and yellow in traffic control. Yet another meaning of the word standards is a measure of quality or value (criteria used to make a judgment). All apply here. The attainment of the vision of science education described in the *Minnesota Science Framework* requires that we identify what students should know

" A hallmark of American education is local control, where boards of education and teachers make decisions about what students will learn. National standards present criteria by which judgments can be made by state and local school personnel and communities, helping them to decide which curriculum, staff development activity or assessment program is appropriate. National standards encourage policies that will bring coordination, consistency, and coherence to the improvement of science education: They allow everyone to move in the same direction, with the assurance that the risks they take in the name of improving science education will be supported by policies and practices throughout the system."

NSES, p. 12

and be able to do, and support the vision with policies and resources. Some of the ways standards will influence the current system include:

- **Content Standards:** Establishing standards for what all children should know and be able to do requires that all children are provided high quality opportunities to learn science. What this means is that ethnicity, economic status, or where you live does not determine what you learn and at each level. This requires attention to two key principles: equity and excellence.
- **Program Design Standards:** Standards provide criteria against which science programs can be judged. Standards purposely and thoughtfully narrow what has become an inflated science curriculum, one that is over-reliant on learning terms or vocabulary and covering vast quantities of material. Standards reduce content to what matters most, with an eye to the achievement of a scientific understanding of the natural world. Science standards focus on important facts, concepts, principles, laws, and theories in a way that provides coherence to science programs. This provides students the opportunity to grow in their understanding of concepts and related ideas. Standards are about focus and coherence. Minnesota's participation in The Third International Mathematics and Science Study (TIMSS) provides evidence that focus and coherence are key to high student achievement, that is, decide what students should learn, teach it and assess for it, and they will perform.

  The scope of standards-based programs for each grade or course emphasizes a limited and carefully selected number of important concepts and skills. These are purposely sequenced throughout a student's school science experiences. There is a major emphasis on learning concepts through scientific inquiry. Understanding of these concepts is facilitated by their use in applications and in personal and social decision-making in science. Standards shift the emphasis from educational "inputs," such as time requirements and curriculum materials, to "outputs," specifically student attainment of standards.

- **Accountability and Responsibility:** Standards provide a set of policies that can be used to inform decisions about the performance of science education programs by both local and state authorities. They require that local and state authorities make decisions and assume responsibility for the science curriculum, the opportunity that all students have to learn, appropriate assessment systems, professional development, and the range of support—intellectual, financial, and political—that teachers need in helping students achieve higher levels of science literacy. A basic assumption is that all individuals in the science education community share the responsibility for leadership.

- **Coherence:** Standards change the school improvement agenda. Rather than focusing attention for, say, the length of a grant period to a highly targeted innovation, often separately staffed and using a variety of specialists to put a program in place, attention in the standards agenda is on the improvement of curriculum, instruction, and assessment and the alignment of all the support systems necessary to realize these on an ongoing basis quite literally day-by-day.

Contemporary Reform in Science Education

Bybee (1996) describes a framework for thinking about systemic change. It is applicable from the local to the national level. This framework includes the effects of the interrelated changes that occur in *purpose*, *policies*, *programs*, and *practices*. These are often referred to as 'The 4 Ps.' This model involves clarifying and reaching agreement on the purpose of science education, establishing policies that support achievement of the purpose, developing science education programs, and changing practices in science classrooms. All four are interdependent and reflect the purpose.

Purpose: Science Literacy for All

The end result of school science is a scientifically literate citizen. The goals that underlie the NSES characterize the nature of such a citizen. The goals for school science are to educate students who are able to:

- experience the richness and excitement of knowing about and understanding the natural world;
- use appropriate scientific processes and principles in making personal decisions;
- engage intelligently in public discourse and debate about matters of scientific and technological concern; and
- increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in his/her career. (NSES, p. 13)

These goals, in concert with the belief statements on which this Framework is based, provide a purpose for science education, a vision, and outline a path for improved learning for all children.

Policy: Aligning State and Local Policies

Policy statements are concrete translations of purpose to the various components of the educational system. These include standards and frameworks; criteria of equity and excellence for curriculum, instruction and assessment; changing requirements for teacher education programs and

Figure 1. Changing Emphasis: State System

Less Emphasis On	More Emphasis On
Independent initiatives to reform components of science education	Partnerships and coordination of reform efforts
Funds for workshops and programs having little connection to the Standards	Funds to improve curriculum and instruction based on the Standards
Frameworks, textbooks, and materials based on activities only marginally related to the Standards	Frameworks, textbooks, and materials adoption criteria aligned with national and state standards
Assessments aligned with the traditional content of science education	Assessments aligned with the Standards and the expanded view of science content
Current approaches to teacher education	University/college reform of teacher education to include science-specific pedagogy aligned with the Standards
Teacher certification based on formal, historically based requirements	Teacher certification that is based on understanding and abilities in science and science teaching

National Science Education Standards,1996

licensure; and a host of other policies that influence science education. In order to achieve the purpose of science literacy, state and local policies must be aligned, that is, be consistent and coherent, in order for goals to be achieved. The changing nature of the policy landscape is outlined in Figure 1.

" Science programs are unique to grade levels, disciplines, and aspects of science teaching and present a consistent, coordinated, and coherent approach to the science education of all students."

Bybee, 1995

Program: Developing Standards-Based Science Programs

Science programs that reflect the *National Science Education Standards* and the *Minnesota Graduation Standards* are based on policies. Program standards move us closer to students. These include the familiar materials of science education: curriculum, textbooks, assessments, equipment and materials, and the "stuff" with which to do science. They must be chosen with care and respect to their contribution to teaching to standards (cf. Chapter Six).

Practice: Teachers & Training

Practice, or instruction, is what teachers do with programs. A teacher's practice includes understandings and beliefs about the purpose of science education, learners and the learning process, curriculum, assessment, images of teaching, as well as the context in which a teacher teaches. While there are other dimensions to a student's opportunity-to-learn, it is teacher practice that will provide opportunities for students to learn how to do scientific inquiry as well as to develop understandings of technology and design, science in personal and social perspectives, and the history and nature of science.

Top Down & Bottom Up

The non-linear nature of the education system and educational change in general means that we cannot focus on only one part of the system at a time and expect overall improvement. Past reform efforts have taught us that lesson. Michael Fullan (1996) points out that neither top-down nor bottom-up reform strategies work by themselves and that both are needed if reforms are to be achieved.

" The only solution is that the whole school—all individuals—must get into the change business." Individuals must "take responsibility for empowering themselves and others through becoming experts in the change process....The solution lies in critical masses of highly engaged individuals working on the creation of conditions for continuous renewal, while being shaped by these very conditions as the latter evolves. ... Paradoxically, the way ahead is through melding individual and institutional renewal. One cannot wait for the other. Both must be pursued simultaneously and aggressively."

Fullan & Stigelbauer, 1991

Reform is articulated from the "top" in terms of national standards, frameworks, state graduation requirements and statewide assessment. The terrain they describe appears less messy and complex than it is. These reforms do not prescribe a specific and identifiable practice. They are strong on promise and no one has fully developed these ideas on any scale in public schools, at least to the level of practice (Ball, 1997). It is here that the "bottom" is so important. This is where vision is turned into practice through selection and enactment of curriculum, assessment and instruction.

Centers of Inquiry

Ball also makes an insightful suggestion about implementing standards in much the same way that is the essence of the scientists' way of thinking about the world. That is, as a series of hypotheses to be tested, data to be collected and analyzed, and hypotheses revised or, at least not rejected, and new hypotheses generated, always "revising the revisions" based on evidence. Schools become "a center of inquiry" (Schaefer, 1967).

While there is nothing tentative about the *Minnesota Graduation Standards* (they are the law), if they are to become vital and viable, they demand an environment in which inquiry by faculty is the norm. Instruction, curriculum, and assessment are studied and hypotheses about them systematically investigated and the results used to make informed decisions about science programs. Examples of questions include: What are the effects of new practices such as project-based science on students' understandings and abilities in inquiry? What is key to standards-based instruction? How can the data we are collecting help to improve teaching and learning for all students?

The Continuum of Systemic Change

Bybee (1996) has analyzed the 4 Ps—purpose, policy, program, and practice—in terms of time for the changes to occur, number of individuals involved in changing a particular decision, the scope of the change, the duration of change once it has occurred, products of the various activities, and the difficulty of reaching agreement on the changes. Everything increases—time, numbers, scale, products, and difficulty. Bybee's analysis suggests that we are "at the interface between policy and program and that we are steering a course toward greater challenges…. The major trend is toward the improvement of science education programs and practices. The issues associated with this trend include the alignment of curriculum materials, assessments, practices, and professional development." This is where we are in implementing the *Minnesota Graduation Standards*.

How can a system, any system from community to governmental, undertake standards-based reforms? Bybee has developed a model for change and improvement known as the Strategies Framework for Standards-Based Reform (see Figure 2). This is an organizer, a way of thinking about reform, strategies, and clarifying responsibilities and authority. While this model is presented as linear, it is important to recognize that it is anything but linear. The dimensions are cyclical and iterative, and they are chaotic in the non-linear sense of this concept.

Figure 2. A Strategic Framework for Standards-Based Reform

Dissemination	Goal: Developing Awareness	"Getting the word out"
Interpretation	Goal: Increasing Understanding and Support	"Getting the idea"
Implementation	Goal: Changing Policies, Programs & Practices	"Getting the job done"
Evaluation	Goal: Monitoring and Adjusting Policies, Programs & Practices	"Getting it right"
Revision	Goal: Improving the Efficacy and Influence of Standards	"Doing it again"

R. Bybee. In NCTM & NRC, (1997) Improving Student Learning in Mathematics and Science: The Role of National Standards in State Policy. Washington DC: National Academy Press.

Moving Ahead

According to Smith and O'Day (1991), standards-based or systemic reform is a process that involves:

- A unifying vision which serves as an umbrella for academic standards, i.e., for what students should know and be able to do as a result of their experiences in school.
- The alignment of policies and standards. These include policies about equity, assessment, teacher preparation, teacher licensure, professional development experiences, and science programs, all of which contribute to a coherent system of instructional guidance.
- A restructured governance system. Minnesota has focused its effort at the state level on the development of student outcomes for graduation and initiated the development of an accountability system. School districts have the responsibility for determining the instructional approaches to meet these broadly worded statements.

However, writing about standards-based and systemic reform is one thing; doing it is quite another. Furthermore, there are few models since we are in the very early stages of these reforms and little has been reported in the professional literature. One thing seems clear, however, and that is the

" The challenge is large, significant, and achievable. It is also too much to place on the shoulders of any one group. Achieving the high standards outlined for science education requires the combined and continued support of all Americans."

NSES p. 245

confusion that exists about standards and implementation. Standards are not something to be "implemented." Deborah Ball (1997) notes that at the heart of the reforms in mathematics (and by implication science) "is a problem of learning." Standards must be the foundation for discussion and reflection. Experiences with standards include learning and unlearning, growth and change. Bybee (1995) describes a timeline of seven to ten years before standards are an integral part of teacher practice. The system must support the time and resources necessary to confront beliefs, learn new content and methods, and change practice. There must be a long term commitment in order for real systemic reform to occur.

There is a rich and growing base of literature on organizational and educational change. This chapter offers a brief overview of a very small piece of this literature. There is still a great deal to learn; much of the "how to" is still to be invented. Indeed, you are the inventors! We are just beginning this journey of improving science education for all students. We have a well defined and challenging purpose in achieving science literacy for all children. The *National Science Education Standards*, the *Minnesota Graduation Standards* and this *Framework* provide direction for policy, programs, and practice. It is now up to each one of us to take responsibility for building a sustainable system that will provide an excellent and equitable science education for all Minnesota children.

References

Anderson, B.L. (1993, Sept.) "The Stages of Systemic Change." *Educational Leadership*, pp. 14-17.

Ball, D. L. (1997). "Developing mathematics reform: What *don't* we know about teacher learning—but would make good working hypotheses." In Friel, S. N. & G. W. Bright (Eds.). *Reflecting on our work: NSF teacher enhancement in K-6 mathematics*. New York: University Press of America.

Bybee, R.W. (1997, October). *Achieving Science Literacy: From Purposes to Practices*. Portsmouth, NH: Heinemann Press.

Bybee, R.W. (1996). "The contemporary reform of science education." In Rhoton, J. & Bowers, P. (Eds.) *Issues in science education*. Washington DC: National Science Teachers Association.

Bybee, R. W. (Ed.) (1996). "Science education beyond standards: Improving programs and practices." In *National standards & the science curriculum*. Dubuque: Kendall/Hunt Publishing.

Bybee, R.W. (1995, October). "Achieving Science Literacy." *The Science Teacher*, pp. 28-33.

Fullan, M.G. (1996, February). "Turning systemic thinking on its head." *Phi Delta Kappan*, pp. 420 - 423.

Fullan, M. G. & S. Stiegelbauer. (1991). *The new meaning of educational change*. New York: Teachers College Press.

Marx, R. W., P. C. Blumenfeld, J. S. Krajcik, & E. Soloway. (1997). "Enacting project-based science." *The Elementary School Journal*, 97:341-358.

National Council of Teachers of Mathematics & National Research Council. (1997). *Imporving student learning in mathematics and science: The role of national standards in state policy*. Washington DC: National Academy Press.

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

Schifter, D. & C. T. Fosnot. (1993). *Reconstructing mathematics education*. New York: Teachers College Press.

SciMath^{MN} (1996). Opening Conversations: An educator's guide to communcating in a changing world. St. Paul, MN: Author.

Smith, M. S. & J. O'Day. (1991). "Systemic school reform." In Fuhrman, S. & B. Malen (Eds.). *The politics of curriculum and testing*. Bristol, U. K.: Falmer Press.