CHAPTER 3

Content and Instruction

"Students' understandings and abilities are grounded in the experience of inquiry, and inquiry is the foundation for the development of understandings and abilities of the other content standards. The personal and social aspects of science are emphasized increasingly in the progression from science as inquiry to the history and nature of science standards. Students need solid knowledge and understanding in physical, life, and earth and space science if they are to apply science."

NSES, p. 104

Content

What students should know, understand, and be able to do is the heart of curriculum. Chapter 3 focuses on the science content all students should have the opportunity to learn as described in the *National Science Education Standards* (NSES) and the *Minnesota Graduation Standards* (MGS).

The NSES describe a view of science content that goes beyond the traditional disciplines. Included alongside life, earth, and physical science are scientific inquiry, science in personal and social perspectives, science and technology, and the history and nature of science. Taken together, the standards in these content areas define the science content that is essential for the development of science literacy in all students.

The science education described in the NSES and the MGS will involve many changes in beliefs and practice. This will mean more of what is called for in the reforms and less of what is done in current practice. However, this does not mean that everything must change or that things will change all at once. Good teachers use a variety of instructional strategies with their students. The goal is achieving balance between the "old" and the "new" practices to ensure learning for all students.

Science Content: Achieving Balance

Achieving balance between	
Knowing scientific facts and information	Understanding scientific concepts and developing abilities of inquiry
Studying subject matter disciplines (physical, life, earth sciences) for their own sake	Learning subject matter disciplines in the context of inquiry, technology, science in personal and social perspectives, and history and nature of science
Separating science knowledge and science process	Integrating all aspects of science content
Covering many science topics	Studying a few fundamental science concepts
Implementing inquiry as a set of processes	Implementing inquiry as instructional strategies, abilities, and ideas to be learned

Adapted from the *National Science Education Standards* ©1996 National Academy Press

"Developing student understanding is not a trivial task. Developing understanding requires that fewer science topics are introduced in science classes and that those topics are studied from multiple perspectives."

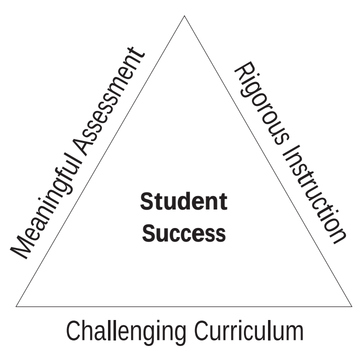
A. Collins, 1996.

A child's education can be thought of as a story, with a story line that starts with beginning learnings and continues throughout his/her life. The story line in science education is one of carefully targeted concepts that are taught by building on prior learnings, and allowing students to expand and modify their understandings and make connections to their lives. An awareness of a child's education as a story provides the context for the development of a curriculum that is rich in inquiry, focuses on significant content at all levels, and is connected. Those responsible for developing, selecting, and teaching the science curriculum must have an understanding beyond their discipline or grade level in order to construct an education program that provides a child a complete story. A knowledge of the content standards at all levels and an understanding of the prior and future development of the concepts being taught provides a context in which complex concepts can be learned and age-appropriate learning experiences can be designed.

The release of the results of the Third International Mathematics and Science Study (TIMSS) provides new insight into the development and delivery of curriculum. This study of forty-one countries examined the intended curriculum, the delivered curriculum, and the learned curriculum in classrooms around the world. Minnesota's participation as a "mini-nation" in this study has enabled us to examine our curriculum and achievement in an international perspective. Minnesota's outstanding performance in the earth and life sciences suggests the value of a focused and coherent curriculum. An informal consensus among middle school teachers to teach seventh graders life science and eighth graders earth science has provided a focus for middle school science curriculum.

This does not mean that the answer to improving student achievement in science is teaching life and earth science at seventh and eighth grades respectively. It does show, however, that if expectations are focused and the curriculum aligns with the expectations, the students will learn. In short, decide what will be taught, teach and assess it, and students will learn. The following pages provide guidance in selecting, developing, and using standards-based curriculum in science programs across Minnesota.

TIMSS shows the most important factors in improving student achievement are a focus on: *What We Teach, How We Teach It, and How We Measure It.*



A Word About Inquiry

Inquiry is central to the *Minnesota Graduation Standards* and the *National Science Education Standards.* Inquiry has many meanings and some form of inquiry can be found in every discipline. Not only is scientific inquiry the heart of science, it is also fundamental to science education. The distinctions between scientific inquiry and inquiry in other disciplines are important as standards-based science curricula, assessment, and instruction are developed and implemented.

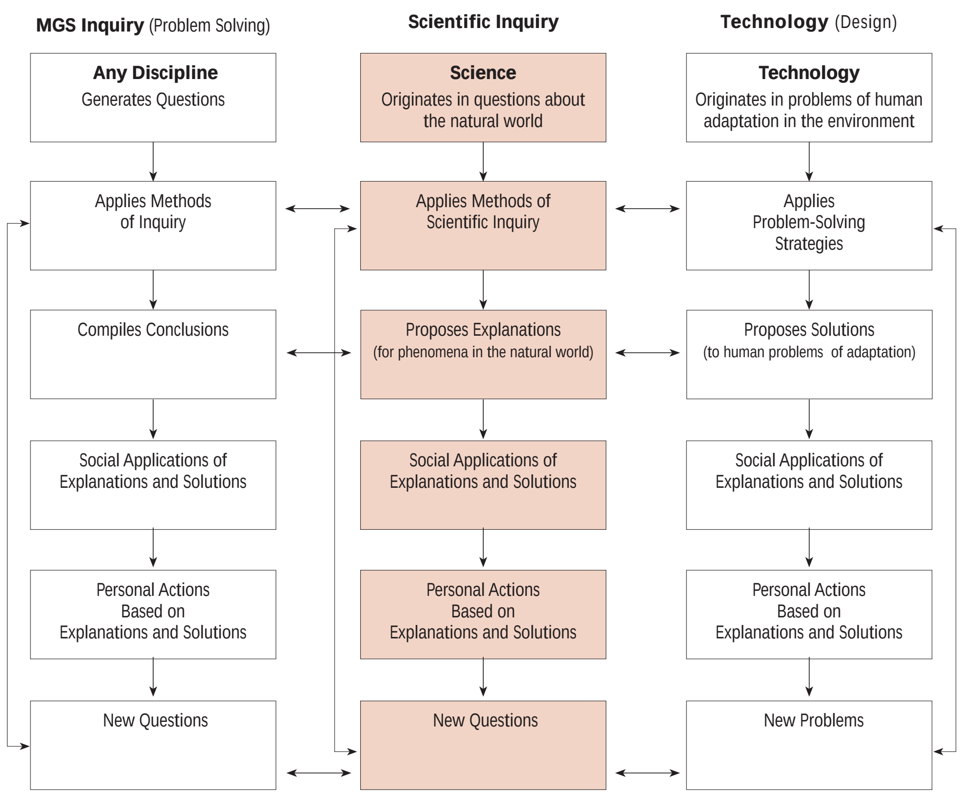
"Science is a way of knowing that is characterized by empirical criteria, logical argument, and skeptical review. Students should develop an understanding of what science is, what science is not, what science can and cannot do, and how science contributes to culture."

NSES, p. 21

The *Minnesota Graduation Standards* define inquiry generally as problem solving in any discipline. The High Standards of the Profile of Learning address inquiry in a variety of disciplines at all levels. Science and technology are closely related and are becoming increasingly interdependent. It is essential that teachers of science understand the similarities and differences between science and technology as they design and implement science curriculum.

The focus of scientific inquiry is proposing explanations for observations about the natural world. Technology, on the other hand, is focused on proposing solutions for problems of human adaptation to the environment. The process of design in technology parallels scientific inquiry, but the purposes and outcomes are inherently different. Figure 1 summarizes similarities and differences in inquiry in the *Minnesota Graduation Standards,* scientific inquiry, and technology as design.

Figure 1



Adapted from Bybee et. al. 1990

The *National Science Education Standards* describe scientific inquiry in terms of content and pedagogy. A firm understanding of the distinctions between inquiry as science content (what students learn) and inquiry as pedagogy (how teachers teach) is important and essential as science curriculum is developed and delivered.

Inquiry As Science Content

"Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry."

NSES, p. 105

Scientifically literate people use scientific methods to investigate questions about the natural world. Because the understandings and abilities necessary to do science have to be learned, they are considered to be science content.

Understandings about scientific inquiry

Understandings about scientific inquiry are an outcome of learning about and participating in inquiry experiences as well as learned through the study of the history and nature of science. Guidelines for these understandings are found in the NSES in both the Inquiry standards and the History and Nature of Science standards. The abilities of scientific inquiry, as described by the NSES, are summarized in the following table.

Abilities necessary to do scientific inquiry:

K-4	5-8	9-12
• Ask a question about objects, organisms and events in the environment	• Identify questions that can be answered through scientific investigations	• Identify questions and concepts that guide scientific investigations
• Plan and conduct a simple investigation	• Design and conduct a scientific investigation	• Design and conduct scientific investigations
• Employ simple equipment and tools to gather data and extend the senses	• Use appropriate tools and techniques to gather, analyze, and interpret data	• Use technology and mathematics to improve investigations and communications
• Use data to construct a reasonable explanation	• Develop descriptions and models using evidence	• Formulate and revise scientific explanations and models using logic and evidence
• Communicate investigations and explanations	• Think critically and logically to make the relationships between evidence and explanations	• Recognize and analyze alternative explanations and predictions
	• Recognize and analyze alternative explanations and models	• Communicate and defend a scientific argument
	• Communicate scientific processes and procedures	
	• Use mathematics in all aspects of scientific inquiry	

Inquiry As Pedagogy

"Inquiry into authentic questions generated from student experiences is the central strategy for teaching science."

NSES, p. 31

The emphasis on scientific inquiry transforms the role of the teacher. S/he is no longer just a primary dispenser of knowledge, but also a resource, guide, coach, advisor, facilitator, thoughtful critic, resource assistant, and cheerleader. These are more demanding roles in that they require the teacher to structure the educational setting in ways that help students construct and work with important ideas in science. The teacher provides information and opportunities for students to learn in the context of a rich learning environment in which the student is an active learner. The teacher creates opportunities for the students to be engaged in acquiring knowledge through investigation and discourse. The learning setting could be in the classroom laboratory, outdoors, or other places where students can learn science. There is less emphasis on dispensing information through lecture and textbooks, and more emphasis on science as a process of meaning making.

Many teachers are familiar with "hands-on" or activity-based science. The challenge is to move beyond discrete activities to inquiry learning that focuses on the big ideas, is developmentally appropriate and includes not only teacher directed experiences, but also those that engage the students in investigating authentic questions drawn from their own experiences within the context of their studies. This means providing opportunities for students to explore content in-depth and enabling them to design and conduct investigations of their own questions. Students develop understanding through active participation in inquiry activities and discussion of their investigations with the teacher and their peers. This does not mean that "any answer goes." The teacher's role is to push for conceptual clarity, and insist on evidence-based justifications and reasonableness of answers.

The NSES Teaching Standards provide direction for instructional practice related to Inquiry.

National Science Education Teaching Standards

A. Teachers of science plan an inquiry-based science program for their students.

B. Teachers of science guide and facilitate learning.

C. Teachers of science engage in ongoing assessment of their teaching and of student learning.

D. Teachers of science design and manage learning environments that provide students with the time, space and resources needed for learning science.

E. Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning.

F. Teachers of science actively participate in the ongoing planning and development of the school science program.

The following table summarizes the change in emphasis in a science program that promotes inquiry. Remember that this is a table of sharp contrasts. Although inquiry is emphasized in the NSES and this *Framework,* it should be understood that there are many ways to teach science. The challenge is to find the right balance of instructional strategies that improve the teaching and learning of science for all students. This table can be used as a springboard for on-going dialogue with colleagues to reflect on where you are as individuals, teams or departments, schools, or districts and where you would like to be. These reflections may challenge or validate your current beliefs and practices.

Changing Emphases to Promote Inquiry

Less emphasis on	*More emphasis on*
Activities that demonstrate and verify science content	Activities that investigate and analyze science questions
Investigations confined to one class period	Investigations over extended periods of time
Process skills out of context	Process skills in context
Emphasis on individual process skills such as observation or inference	Using multiple process skills–manipulation, cognitive, procedural
Science as exploration and experiment	Using evidence and strategies for developing or revising an explanation
Getting an answer	Science as argument and explanation
Providing answers to questions about science content	Communicating science explanations
Individuals and groups of students analyzing and synthesizing data without defending a conclusion	Groups of students often analyzing and synthesizing data after defending conclusions
Doing few investigations in order to leave time to cover large amounts of content	Doing more investigations in order to develop understanding, ability, values of inquiry and knowledge of science content
Concluding inquiries with the result of the experiment	Applying the results of experiments to scientific arguments and explanations
Management of materials and equipment	Management of ideas and information
Private communication of student ideas and conclusions to teacher	Public communication of student ideas and work to classmates

Chapter 2: Best Practice and the NSES Teaching and Assessment standards provide more information about teaching inquiry at all levels.

Implications of Scientific Inquiry in Curriculum Planning

Assessment

Assessment is the key to monitoring the effectiveness of instruction and learning. There are close links among curriculum, instruction, and assessment and, as curriculum and instruction change, so must assessment. Assessments must mirror what we really want students to know and be able to do. Performance assessments, alternative assessments, and authentic assessments are some of the labels used to describe these new methodologies. Minnesota's performance packages, which are designed to assess the *Minnesota Profile of Learning,* provide some examples of new assessment possibilities, as do professional journals and other publications. Students should be provided with a variety of opportunities to demonstrate their understandings and abilities in science. *Chapter 2: Best Practice, and the NSES Assessment Standards provide more insight and information about assessment in science.*

Safety

Scientific inquiry naturally involves students working in the laboratory and in the field as they participate in hands-on activities. This may involve using a variety of equipment, chemicals, and/or locations that are potentially hazardous. The teacher is responsible for ensuring a safe working environment for students. Students, in turn, are responsible for acting within established safety guidelines provided by the teacher. In addition, school administrators and the school community must meet their responsibilities in providing adequate resources for safe school science programs. All teachers of science, K-12, must be familiar with all potential safety hazards, discuss these hazards with students, and provide appropriate equipment and direction to create a safe learning environment. *See Chapter 6: Resources, for more detailed information regarding safety in the elementary and secondary classroom.*

Unifying Concepts & Processes

In addition to the content areas previously described, the NSES identifies broad concepts and processes that can provide students with other perspectives or understandings about science. Unifying Concepts and Processes are fundamental ideas that provide powerful and comprehensive connections between and among the traditional science disciplines at all grade levels. They provide students with productive and insightful ways of thinking about and integrating a range of basic ideas that help explain the natural and designed world. The understanding of these concepts and processes should be developed throughout a K-12 science program. *See the NSES, pages 115-119, for an explanation of the Unifying Concepts and Processes and Chapter 4: Connections, of this Framework for suggestions for integrating these into the curriculum.*

How To Use This Chapter

The sections of this chapter of the *Minnesota K-12 Science Framework* correspond to the grade ranges (K-4, 5-8, 9-12) and content areas described in the *National Science Education Standards (NSES)*. Each section begins with an overview of content and important developmental characteristics of learners within a grade range. This is followed by a table that summarizes the focus of instruction in all the content areas within that grade range.

Each grade range is divided into the seven disciplines outlined in the NSES. Each discipline is coded with colors and icons that correspond throughout grades K-12. An organizing graphic summarizes the relationship between the *MN Graduation Standards Profile of Learning* (MGS) and the NSES. The MN Primary Level Standards are found in the K-4 sections, the MN Intermediate and Middle Level Standards are found in the 5-8 section and the MN High School Standards are contained in the 9-12 section.

The organizing graphic is followed by a table that summarizes the focus of instruction within the content discipline, K-12. It provides a context for conceptual development within that discipline. "Close-Up," a brief narrative that describes the focus of instruction in the grade range, follows. These narratives are based on the NSES and the experience and insights of many Minnesota teachers who have been active in the development of this Framework. Information regarding the content, instruction, and context for learning is included in these short narratives. These narratives are offered only as a beginning. They do not replace the standards, but provide direction for curriculum and instruction.

"On Location" are sample vignettes illustrating the teaching and learning that is found in the vision of the NSES and this *Framework*. They are not intended to be lesson plans, but provide a snapshot of exemplary classroom experience within the content area described. These vignettes have been inspired by and are based on the classroom experiences of Minnesota teachers. Each vignette begins with a sentence or two (in italics) showing connections to the NSES.

The development of the MGS has been influenced by the NSES. The NSES and the MGS are not a curriculum — curriculum development is a local task. The *Minnesota K-12 Science Framework* allows side by side comparisons of the NSES and MGS so that as a local science curriculum is developed, connections between the two can be seen and informed decisions about curriculum choices can be made.

It is of utmost importance that the material presented in this chapter is not divorced from the rest of the *Framework* or from the *National Science Education Standards.* The NSES Teaching, Professional Development, Assessment, Program, and System Standards all make important contributions to the way the content in this chapter is taught, learned, assessed, and how it is to be supported at the program and system levels. The remaining chapters of the *Minnesota K-12 Science Framework* provide insight and direction for the development of standards-based science programs founded in excellence and equity.

Resources

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