CHAPTER 4

Connections

"If teachers are to teach for understanding as described in the [NSES] content standards, then coverage of great amounts of trivial, unconnected information must be eliminated from the curriculum. Integrated and thematic approaches to curriculum can be powerful; however they require skill and understanding in their design and implementation."

NSES, P. 213

Chapter 4

The Importance of Connections

" Among the various aims we consider important in education, two are especially so. We would like our children to be well informed — that is, to understand ideas that are important, useful, beautiful, and powerful. And we also want them to have the appetite and ability to think analytically and critically, to be able to speculate and imagine, to see connections among ideas, and to be able to use what they know to enhance their own lives and to contribute to their culture."

Eisner, 1997

Whether it is in the workplace, in the voting booth, at the grocery store, or a walk in the park, there are very few experiences that we encounter one subject at time. Schooling, it seems, is one of those times when students are expected to concentrate on one discipline at a time. Most learning is so compartmentalized that students are rarely given the opportunity to make connections among their learnings or to life situations. This is not to say that there is not merit in learning about the world one discipline at a time. There are times when this makes educational sense. Where students are shortchanged, is in having opportunities to make connections that allow them to develop a fuller understanding of the natural and designed world.

The body of scientific knowledge is immense and growing at an exponential rate. It is impossible and not necessary to teach all the content or all the applications. *Chapter Three: Content and Instruction* identifies the science content that all students should have the opportunity to learn. While a strong foundation of science knowledge is important, instruction that includes opportunities for students to make connections enhances the development of science literacy.

Students are not blank slates upon which the knowledge of science is written. They come to school with a variety of experiences and personal constructs about the natural and designed world. When students are provided with experiences that introduce them to new knowledge or ideas, they make connections to what they already know and develop their own understandings. If we leave the connecting solely to the students, they will put things together in ways that make good sense to them, but may develop or reinforce misconceptions that are very hard to dislodge. Students will make connections to what they already know, whether we like it or not. It is critical that students participate in experiences that enable them to build accurate and powerful conceptual connections. The quality of their learning, and their ability to access and use their knowledge and understandings in the future, depends on the quality and quantity of the connections between those pieces of knowledge and their applications. It is the role of the teacher to help students build solid, logical constructs with broad utility for explanation and prediction so that when they encounter a new idea or application they can accurately connect it to what they already know.

A scientifically literate person must not only have an understanding of science content, but be able to make connections within the sciences, to disciplines other than science, and to apply science knowledge and understandings in a variety of life situations. The *National Science Education Standards* (NSES), the *Minnesota Graduation Standards*, and the *Minnesota K-12 Science Framework* describe a vision of science education that, when implemented, will result in a collection of coherent experiences that students can use in school, beyond the science classroom to other classrooms as well as outside the classroom, and as a basis for their emerging citizenship in a world that increasingly relies on science and technology.

We live in an interconnected world. As we strive to help all students develop scientific literacy, it is essential that a variety of curriculum, instruction, and assessment practices be explored and used. Preferred learning styles, along with gender, ethnic, cultural, and economic backgrounds of students, must be addressed. The needs of all students are likely to be met by providing a variety of connections through curriculum and applications.

Chapter Four: Connections is intended to provide a starting point for structuring curriculum, instruction, and assessment to help students make the connections that are at the heart of the standards. Connections within the science disciplines, connections with other disciplines, and connections both in and out of the classroom are described. In addition, a guide for making curriculum decisions designed to facilitate the construction of rich and productive connections is included.

Types of Connections

"Today, some people criticize educators for not adequately teaching basic skills; others argue that the basic skills students will need for the 21st century are not the same skills that we are now teaching. The knowledge component of virtually every subject area is proliferating at an ever-increasing rate. Paradoxically, as distinct subject areas become overloaded, a surprising amount of duplication is occurring across classrooms. Educators are caught in a dilemma. Integration, by reducing duplication of both skills and content, begins to allow us to teach more. It also gives us a new perspective on what constitutes basic skills."
Drake, 1997, p. 2

The idea of helping students make connections has been around for many years under many different names. Historically, we have examples of efforts to make application connections, such as the Project Approach suggested by John Dewey. Today, if you walk into most schools, secondary or elementary, you are likely to hear words and phrases related to connections, such as theme-based, integration, application-driven, strand-based, spiraling, webbing, and project-based. If you examine any of the many books published about making connections, you will find that each one uses these terms in a slightly different way.

The connections described in this *Framework* are organized into three groups: discipline-based connections, theme-based connections, and application-based connections. This classification system does not exhaust the possibilities, but it is helpful in thinking about how science is organized and taught.

Discipline-based Connections

Connections Within the Sciences

Although they may be used somewhat differently from discipline to discipline, science concepts rarely belong only to one science discipline. Connections that draw together the ideas of many science disciplines may help students develop a more coherent, transferable understanding of the concept or process they are learning. Without such connections students may view the learning as unrelated and discrete and have little understanding of how their learnings relate to larger concepts. Teachers can support the development of these connections through careful unit construction, appropriate questioning, and by teaching students to use devices such as graphic organizers. The intent is to help students gain conceptual understanding that stretches beyond the bounds of one discipline or grade level. Assessment of these learnings focuses on students' understanding of big ideas, rather than the bits and pieces of science.

The NSES provide rich opportunities for making connections in science. The inclusion of Inquiry, Science and Technology, Science in Personal & Social Perspectives, and the History and Nature of Science, along with the traditional areas of Physical Science, Life Science, and Earth and Space Science, in the content standards provide a vision for science teaching and learning that includes making connections throughout a science program. Please see *Chapter 3: Content and Instruction* for more information about these content areas.

Unifying Concepts & Processes

As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes:

- Systems, order and organization
- Evidence, models and explanation
- Constancy, change and measurement
- Evolution and equilibrium
- Form and Function

NSES, p. 115

Science educators have identified a number of unifying concepts and processes in science. These conceptual and procedural schemes complement the analytic, more discipline-based perspectives presented in the other content standards and provide students with productive and insightful ways of thinking about and integrating a range of basic ideas that explain the natural and designed world. They are powerful ideas that cut across discipline boundaries and provide ways of thinking about science. The NSES identify unifying concepts and processes that are fundamental and comprehensive, understandable, developmentally appropriate and have the potential to connect ideas within the traditional science disciplines.

Each of the unifying concepts and processes included in the NSES has a continuum of complexity that should be learned and experienced by all students K-12. In the early grades, the meaning and use of these concepts and processes should be emphasized. In the upper grades, these concepts and processes provide students with a "big picture" of scientific ideas that can facilitate and enhance the learning of science concepts and principles.

An example of this type of connection is found in the life sciences. A typical approach to teaching about the various plant groups would focus on the names of the groups and their characteristics.

Alternatively, the unit could be drawn together around the unifying concept of form and function. This second approach provides students with a powerful concept which they can use and apply when studying other plants or other areas such as animals or automobiles. Assessment focuses on the larger concept of form and function and not the details of the plants studied.

A word of caution is appropriate here. Many publishers have developed curricula which are described as integrated, especially at the middle school level. Care must be taken to ensure that the materials are truly integrated—that connections are used to improve student learning — rather than simply being an example of a "general" science curriculum, with some physical, life and earth science placed together in one book with no attempt at helping students construct connections.

Connections Across Grades K-12

All students come to school with knowledge and understandings about the natural and designed world. When teachers take advantage of students' prior knowledge, they are increasing the potential for facilitating student understanding at higher levels and helping students make connections. A well designed K-12 curriculum brings consistency and coherence to students' school experience and clarifies the construction of major ideas throughout a child's education so that new understandings can build on previous learnings. Teachers must be aware of not only the content in their course or grade level, but also have an understanding of how concepts are developed across the school science curriculum. By defining a curriculum that deliberately and systematically develops student understanding across grades K-12, it is more likely that the curriculum taught at each grade is developmentally appropriate, and that the opportunity to learn concepts at more sophisticated levels occurs throughout a student's school experience. See *Chapter 6: Resources* for direction in developing K-12 standards-based science programs and *Chapter 3: Content and Instruction* for K-12 development of science concepts.

Connections With Disciplines Other Than Science

Program Standard D:
"The science program should be coordinated with the mathematics program to enhance student learning and understanding of mathematics in the study of science and to improve student understanding of mathematics."
NSES, p. 214

There are many concepts and skills of science that play a critical role in disciplines outside science. Interdisciplinary connections are those where instruction takes advantage of such commonalties. For example, science, math, and social studies all require students to produce and interpret graphs. Yet, because the format, grading, and instruction can appear different from the students' point of view, graphing may be seen as three different skills. There are many other skills, such as classification, observation, describing, and using numbers, that also extend across many disciplines.

Concepts that are common across disciplines offer rich opportunities for interdisciplinary integration. Balance is an example. It has common characteristics that are evident across art, social studies, health, physics, and biology. Students build a more complete, powerful and transferable understanding of balance if they make solid connections among all of these areas. Making this type of connection can prove to be difficult because it requires:

- that each teacher has an understanding of the fundamental skills and concepts in each discipline (what is taught).
- that the teachers involved are aware of and have some knowledge about the curriculum in the other discipline(s) (how it is taught).
- that teachers agree on what the skills and concepts mean. If the meanings are substantially different between the areas, attempts to connect them may cause more confusion than understanding.

Theme-based Connections

In contrast to the discipline-based connections described above, theme-based connections bring together many concepts or skills from one or many disciplines and use a common theme as an instructional strategy. The purpose of using a theme is to provide the student with a motivating context to connect learnings in many disciplines. The theme, or carrier, is not what students are to learn, but simply something that holds ideas together for instructional convenience. Theme-based instruction is sometimes referred to as multidisciplinary instruction.

"All too often, cute, accessible, but shallow themes like transportation are chosen. There is another hazard, however, when a rich theme is dealt with superficially.... It takes careful thought about themes to find a good "lens" that will ensure a rich look at the subject matter involved."
Perkins, 1989

"The circus" is a frequently used theme. Mathematics, science, language arts, art, and social studies can all be taught using a circus theme. In this theme, the instruction and assessment are not focused on students' understanding of the circus, but rather on the knowledge, skills, and understandings related to each of the disciplines. The circus theme is woven throughout the unit, and many examples in the various disciplines relate to the circus. However, the outcomes and the assessments focus on the content in each of the disciplines, rather than the circus. While this approach may improve student motivation, it may not provide useful connections. It is important to evaluate thematic curriculum to make sure that time is not invested in efforts that are more entertaining than educational.

Application-based Connections

Application-based connections are more than learning about the uses of polymers, that all ecosystems have a carrying capacity, or that engineers use Newton's Laws. These connections are designed to help students relate their learnings to issues and contexts outside of school. They provide students with the opportunity to learn and use their knowledge, skills, and understandings through authentic experiences.

There are a wide range of application-based connections. They can be found in the classroom, outside school, or in the workplace. They range from authentic encounters with the natural or designed world, to volunteer or workplace experiences, to involvement in decision making about local issues.

"There should be no division between academic and vocational education, as they are both needed for the education of all the children of all the people."
Penn & Williams, 1996

Application-based connections have typically been the domain of vocational programs. However, there is a growing understanding in both the academic and vocational communities that the integration of academic and applied learning is essential for increased learning by all students. The *Schools that Work* program from the Southern Regional Education Board is showing increased achievement by connecting college preparatory level academic courses with modern vocational courses in a planned program of study. Some Minnesota schools are developing similar programs that integrate challenging academic and technical content and engage students in authentic learning activities that allow them to apply their learnings to situations in and outside the classroom.

Life Readiness Connections

These application-based connections emphasize the development of skills and understandings necessary for applying their understandings about the natural world, and the decisions they will make as adults. Many science concepts can be taught using environmental and economic connections. Students' motivation improves when the science they are learning enables them to influence and take action on critical societal issues.

Opportunities to make life readiness connections within the context of the classroom are plentiful. Along with learning science content, teachers provide opportunities for students to make connections that help them use their knowledge to better understand the natural and designed world. An example of this is learning about electricity. Students learn about circuits and switches through ex-

periences with batteries, bulbs, switches, and wire. They frequently draw and construct circuits and make predictions about whether they will work or not. Lights, outlets, and appliances all contain circuits and switches similar to the ones they have studied. Extending their learning through discussions and experiences with these provides connections between their learnings and the electricity that is used in their classroom and home. These connections enable them to further develop their understandings about electricity.

" Service-learning is a method by which young people learn and develop through active participation in thoughtfully organized service experiences...

- *that meet community needs;*
- *that are coordinated in collaboration with the school & community;*
- *that are integrated in each young person's academic curriculum;*
- *that provide structured time for a young person to think, talk, and write about what he/she did and saw during the actual service activity;*
- *that provide young people with opportunities to use newly acquired academic skills and knowledge in real life situations in their own communities;*
- *that enhance what is taught in the school by extending student learning beyond the classroom;*
- *that help to foster the development of a sense of caring for others."*

The Alliance for Service-Learning in Education Reform, 1993

Service-learning integrates community service into the school curriculum. Young people engage in community activities where they apply their academic knowledge and skills as they solve real-life problems. At the same time, these activities help students realize the importance of having a good understanding of science concepts, the meaning of citizenship, and their ability to help determine the quality of life in their communities.

Work-based Connections

In recent years, state and national attention has been drawn to school-to-work programs. These programs stress the connections between school learning and workplace skills. There are many ways to show connections to the workplace in the classroom. Invited speakers can share their stories and skills, describe how they learned science and how they use it in their employment. Many companies produce activities for the classroom that provide students with experiences that are representative of what takes place in the workplace. There are also curriculum projects available that show connections between student learning and work-based applications within the classroom setting. These "Tech Prep" curricula teach science concepts in the context of occupational experiences. Connections are made through experiences in the classroom that link science content to how that content is used in the work place.

Student experiences that connect science concepts to the work world is another application-based connection. Work-based learning programs use internships with employers to explore career opportunities, develop employment skills, and acquire specific job skills. Work-based learning opportunities can include internships, apprenticeships, community or school-based entrepreneurships, and student-run enterprises.

Application-based connections can be a powerful tool for improving student understanding. Connecting learning to events and activities in students' lives enables them to develop understandings that will last a lifetime. However, it is essential that the central learnings of application experience in science are rooted in science content. The application is a vehicle for teaching the science content and it is important that the science content does not get lost in the experience. Science knowledge, skills, and understandings must be at the forefront of curriculum decisions regarding application-based connections in science.

Describing ways to provide opportunities for connections is useful, but it is just the first step. The harder questions have to do with which connections to choose and when to use them in such a way that student learning will be enhanced. The effectiveness of our teaching and the quality of our students' learning depends on these decisions.

What's Worth Connecting?

There are an infinite number of possible connections to be made in science instruction. The difficult part is not finding connections, but identifying those connections that are the most powerful and useful to students and constructing meaningful opportunities for students to make these connections. Because designing these opportunities requires a substantial investment of time on the teachers part, it is critical that the connections chosen are significant.

There are many processes that can be used to design curriculum that provides opportunities to make connections. The essential features in a process designed to help guide curricular and classroom decisions are summarized in Figure 1 and is described below. This process is designed to explore and open possibilities for orchestrating connections and then to narrow the possibilities to the most powerful connections. It can be used to explore discipline-based connections, application-based connections or theme-based connections. While at first glance the process seems to be linear, the steps are interrelated and when it is used will not be cut and dried. This guide is to be used in the exploration of opening a traditional curriculum to one that is connected in the classroom and beyond.

Start with standards. Decide which curriculum content and processes will be addressed and what you expect students to learn by making these connections. If you are connecting with other disciplines, each discipline should do this and collaboration with other teachers is essential. You will probably need to prioritize standards as you move through the process.

Identifying possible conceptual connections. Brainstorm many possible connections that could be made. The purpose of brainstorming is to develop a rich list of possibilities, so avoid making positive and negative judgments. Often the most powerful connections are those that, at first glance, seem trivial or off the wall.

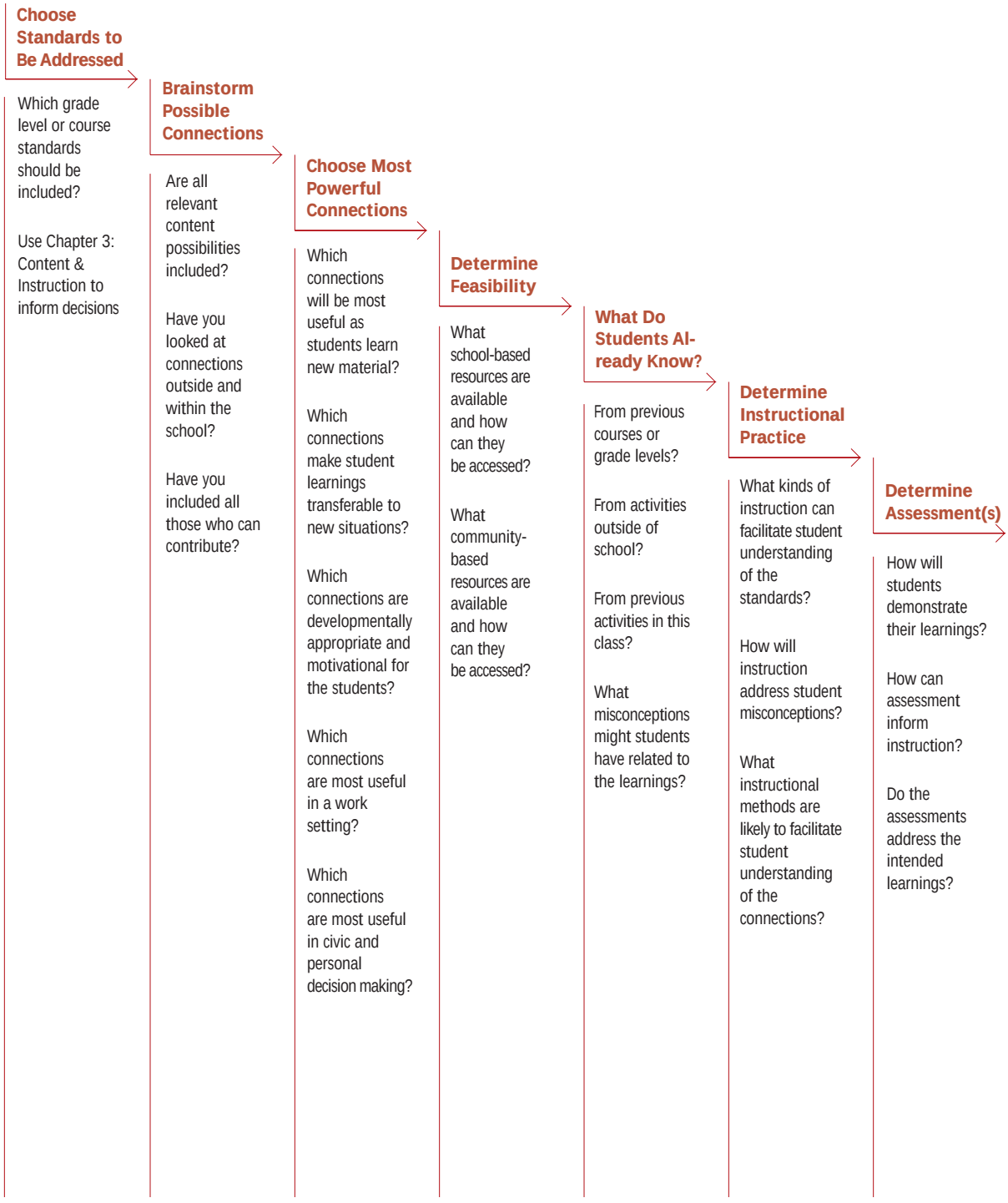
Identifying the most powerful connections. Which of the connections will be most useful to students as they try to make sense out of new material? Which connections enable students to transfer their learnings to new situations? Which connections will be most useful to students in developing employment skills? Which connections will be most useful in civic and personal decision making? Which connections are developmentally appropriate and motivational for the students?

Examine feasibility. What resources are needed to teach the selected connections? These resources may involve school structure, time, technology, materials or curriculum. They also include community resources such as business and industry partners, parents, funding agencies, speakers, higher education institutions, outdoor sites, museums, and nature centers. Avoid making superficial connections just because a resource is available. Emphasize the resources that will facilitate the strongest learning connections. *Chapter 6: Resources* lists many resources that are available to teachers as they plan programs.

Identify what students already know. What do students already know from activities outside of school; from previous activities in this class; and from previous courses or grade levels? What are possible student misconceptions that would interfere with their understanding? What strategies might be used to take advantage of what students know, whether or not it is scientifically correct?

Determine instructional practice and assessment. There are many tools available for planning lessons and units that emphasize connections (see references at the end of this chapter). The task is insuring instruction that uses connections to help students learn the selected standards. The assessments must be aligned with the standards and the instruction. Once this is done, the fun begins!

Figure 1. Planning for Connections



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