Chapter 6

About Standards

Overview

In Chapter 3, "Activities," we have listed standards references for each activity. This type of listing is now found in most curriculum materials, in order to demonstrate that the activities "meet standards." In a way, these standards references miss the point, because the national standards are not meant to be read in this way. Meeting standards is not about checking off items from a list. Each of the major standards documents is a coherent, comprehensive call for systematic change in education.

This chapter shows how *Stuff That Works!* in general and *Mechanisms and Other Systems* in particular are consistent with national standards at a very fundamental level. We will look in detail at the following documents:

- *Standards for Technological Literacy: Content for the Study of Technology* (International Technology Education Association, 2000);
- *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993);
- *National Science Education Standards* (National Research Council, 1996);
- *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics, 2000);
- *Standards for the English Language Arts* (National Council of Teachers of English & International Reading Association, 1996); and

Most of these standards are now widely accepted as the basis for state and local curriculum frameworks. The first document on the list is included because it is the only national standard focused primarily on technology. The *New Standards Performance Standards* (National Center on Education and the Economy, 1997) is not included because it is based almost entirely on the *Benchmarks, National Science Education Standards,* the original NCTM *Math Standards* (1989) and the *Standards for the English Language Arts.*

Although they deal with very different disciplines, these major national standards documents have many remarkable similarities:

- They are aimed at *all* students, not only those who are college-bound.
- Using terms like "literacy" and "informed citizen," they argue that education should prepare students to understand current issues and participate in contemporary society.
- They recommend that school knowledge be developed for its use in solving real problems rather than as material "needed" for passing a test. They strongly endorse curriculum projects that arise from students' own ideas, experiences, and interests.
- They focus on the "big ideas" of their disciplines as opposed to memorization of isolated facts or training in narrowly defined skills. In other words, fewer concepts should be dealt with in greater depth. As the *National Science Education Standards* express it, "Coverage of great amounts of trivial, unconnected information must be eliminated from the curriculum." (NRC, 1996, p. 213)

- The standards reject standardized tests as the sole or even the major form of assessment. Traditional exams measure only what is easy to measure rather than what is most important. "While many teachers wish to gauge their students' learning using performance-based assessment, they find that preparing students for machine-scored tests – which often focus on isolated skills rather than contextualized learning – diverts valuable classroom time away from actual performance." (NCTE/IRA, 1996, p. 7) The standards promote authentic assessment measures, which require students to apply knowledge and reasoning "to situations similar to those they will encounter outside the classroom." (NRC, 1996, p. 78) Furthermore, assessment should become "a routine part of the ongoing classroom activity rather than an interruption" and it should consist of "a convergence of evidence from different sources." (NCTM, 2000, p. 23)
- They highlight the roles of quantitative thinking, as well as oral and written communication, in learning any subject, and they emphasize the interdisciplinary character of knowledge.
- They view learning as an active process requiring student engagement with the material and subject to frequent reflection and evaluation by both teacher and learner.
- They urge teachers to "display and demand respect for the diverse ideas, skills and experiences of all students," and to "enable students to have a significant voice in decisions about the content and context of their work." (NRC, 1996, p. 46)

The ***Stuff That Works!*** materials are based on these ideas and provide extensive guidance on how to implement them in the classroom. We begin our study of technology with students' own ideas and experiences, address problems that are of importance to them, develop "big ideas" through active engagement in analysis and design, and draw connections among the disciplines. While the standards are clear about the principles, they do not provide many practical classroom examples. ***Stuff That Works!*** fills this gap.

Where the Standards Came From

Historically speaking, the current tilt towards national curriculum standards is a dramatic departure from a long tradition of local control of education. How did national standards manage to become the order of the day? In the late 1970's, the country was in a serious recession, driven partly by economic competition from Europe and Japan. In 1983, the National Commission on Educational Excellence (NCEE) published an influential report, *A Nation at Risk,* which painted a depressing picture of low achievement among the country's students. The report warned of further economic consequences should these problems continue to be ignored, and advocated national curriculum standards for all students. Adding to these arguments were pressures from textbook publishers, who felt that national standards would make state and local adoption processes more predictable.

Around the same time, several of the major professional organizations decided to provide leadership in setting standards. The pioneering organizations were the National Council of Teachers of Mathematics (NCTM) and the American Association for the Advancement of Science (AAAS), whose efforts culminated in the publication of major documents in 1989. In the same year, the National Governors' Association and the first

Bush Administration both endorsed the concept of establishing national educational goals. The NCTM was deeply concerned about the issues raised by *A Nation at Risk* and was convinced that professional educators needed to take the initiative in setting a new educational agenda. Otherwise, the reform of curriculum would rest in the hands of textbook and test publishers, legislatures, and local districts.

Both the NCTM and the AAAS standards projects began with similar basic positions about pedagogy. Influenced by research about what children actually know, they recognized the disturbing fact that "learning is not necessarily an outcome of teaching." (AAAS, 1989, p. 145) In contrast with traditional approaches to education, which emphasize memorization and drill, the new national standards promote strategies for active learning. A related theme of the early standards efforts was that the schools should teach fewer topics in order that "students end up with richer insights and deeper understandings than they could hope to gain from a superficial exposure to more topics..." (p. 20)

Meeting standards requires a major investment of time and resources. Some of the necessary ingredients include new curriculum ideas and materials, professional development opportunities, new assessment methods, and smaller class sizes. The *National Science Education Standards* are the most explicit in identifying the conditions necessary—at the classroom, school, district, and larger political levels—for standards to be meaningful. The authors state, "Students could not achieve standards in most of today's schools." (NRC, 1996, p. 13) More money might not even be the hardest part. Standards-based reforms also require understanding and commitment from everyone connected with the educational system, starting at the top.

The history of standards may contain clues about their future. Standards imply neither textbook-based instruction nor standardized tests. Standards arose because traditional text- and test-based education had failed to result in the learning of basic concepts by the vast majority of students. Ironically, there are many textbook and test purveyors who market their products under the slogan "standards-based." Standards could easily become discredited if those who claim their imprimatur ignore their basic message.

What the Standards Actually Mean

Standards are commonly read as lists of goals to be achieved through an activity or a curriculum. This approach is reflected in the lists of standards references and cross-references that appear in most curriculum materials, as evidence that an activity or curriculum "meets standards." In the "Activities" chapter of *Mechanisms and Other Systems,* for example, we have listed the following reference under the activity "What Does a Tool Do?":

> "By the end of second grade, students should know that tools are used to do things better or more easily and to do things that could not otherwise be done at all." (AAAS, 1993, p. 45)

Presenting lists of outcomes in this fashion reflects a narrow reading of standards, which can be very misleading. These lists suggest that "meeting standards" is simply a matter of getting students to repeat something like the statements found in the standards documents, such as the one quoted above.

In fact, the standards are much richer and more complex than these lists imply. Many of the standards do not even specify the knowledge that students should acquire, but deal rather with ways of using that knowledge. Here is another example from *Benchmarks for Science Literacy:*

"By the end of fifth grade, students should be able to write instructions that students can follow in carrying out a procedure." (p. 296)

This standard talks about something students should be *able to do,* rather than what they should *know.* The newly released NCTM document, *Principles and Standards for School Mathematics* (2000), unlike the earlier one (NCTM, 1989), explicitly separates "Content Standards" from "Process Standards." The Content Standards outline what students should learn, while the Process Standards cite ways of acquiring and expressing the content knowledge. The Process Standards include problem solving, communication, and representation. The *Benchmarks* example just cited above is another example of a process standard. Similarly, in the English Language Arts (ELA) document (NCTE/IRA, 1996), all twelve standards use verbs to express what students should *do,* as opposed to what they should *know.* Any reading of standards that focuses only on content knowledge is missing a central theme of all of the major documents.

There is also material in the standards that qualifies neither as content nor as process. Here is an example from the *Benchmarks* chapter called "Values and Attitudes":

"By the end of fifth grade, students should raise questions about the world around them and be willing to seek answers to some of them by making careful observations and trying things out." (p. 285)

This standard asks for more than a specific piece of knowledge, ability, or skill. It calls for a way of looking at the world, a general conceptual framework, that transcends the boundaries of disciplines. Similarly, the "Connections" standard in the new NCTM document underscores the need for students to ...

"...recognize and apply mathematics in contexts outside of mathematics." (NCTM, 2000, p. 65)

These are examples of broad curriculum principles that cut across the more specific content and process standards. These standards are not met by implementing a particular activity or by teaching one or another lesson. They require an imaginative search for opportunities based on a reshaping of goals for the entire curriculum.

In general, the standards documents are at least as much about general principles as about particular skills and knowledge bases. The *Standards for Technological Literacy,* the *Benchmarks,* and the *National Science Education Standards* each identifies some big ideas that recur frequently and provide explanatory power throughout science and technology. "Systems" and "modeling" are concepts that appear in all three documents. The presence of such unifying ideas suggests that the individual standards references should not be isolated from one another. They should rather be seen as parts of a whole, reflecting a few basic common themes.

What Use Are Standards?

Increasingly, teachers are being held accountable for "teaching to standards." These demands are added to such other burdens as paperwork, test schedules, classroom interruptions, inadequate space and budgets, arbitrary changes in class roster, etc. In the view of many teachers, children and their education are routinely placed dead last on the priority list of school officials. Understandably, teachers may resent or even resist calls to "meet standards" or demonstrate that their curricula are "standards-bearing." It is not surprising that many teachers cynically view the standards movement as "another new thing that will eventually blow over."

The push to "meet standards" is often based on a misreading of standards as lists of topics to be "covered" or new tests to be administered. It is not hard to imagine where this misinterpretation might lead. If the proof of standards is that students will pass tests, and students fail them nevertheless, then the standards themselves may eventually be discarded. Paradoxically, the prediction that "this, too, shall pass" would then come true, not because the standards failed, but because they were never understood nor followed.

Standards are intended to demolish timeworn practices in education. Some of these practices place the teacher at the center of the classroom but reduce her or him to a cog in the machinery of the school and the district, with the primary responsibility of preparing students for tests. The standards documents recognize the need to regard teachers as professionals, students as active, independent learners, and tests as inadequate methods of assessing the full range of learning.

Within broad frameworks, the standards urge teachers to use their judgment in tailoring the curriculum to students' needs and interests. The NRC *Science Standards*, for example, call for "teachers [to be] empowered to make the decisions essential for effective learning." (1996, p. 2) Neither teachers nor administrators should interpret standards as mechanisms for tightening control over what teachers and students do. While they are very clear about the goals of education, the standards are less specific about how to meet them. Innovative curriculum efforts such as *Stuff That Works!* fit very well within the overall scheme of standards.

Teachers who have tried to implement *Stuff That Works!* activities in their classrooms have often come away with a positive feeling about them. The following comments are typical:

- *The strengths of this unit are the opportunity to group students, work on communication skills, problem solve … and plan real life tests. I have watched my students go from asking simple yes/no questions to thinking and planning careful, thoughtful active questions. The students began to see each other as people with answers... I was no longer the expert with all the answers.*
- *At second grade, with basically no prior knowledge of mechanisms, I wanted the students to start to analyze/take apart objects around them.... Most of my students really enjoyed working with mechanisms. I noticed that more girls participated in discussion than with some of my previous science activities.*
- *I must begin by telling you that I found this particular guide to be so much fun and the students demonstrated so much energy and interest in this area... I was able to engage them in the activities easily... The activities were very educational and provided so much vital information that helped students connect what is being taught to them in math to real life situations, e.g., graphing behavior and using tallies to record information. For my [special education] students, I found this gave them self confidence...*
- *I read the entire guide from front to back... Although the main idea of the unit is not specifically a large focus of instruction in our fourth grade curriculum, I recognized the power behind the*

ideas and activities and knew that this unit would promote collaboration, problem solving and communication... Overall, I think my students loved this unit and felt enormously successful after we finished...

- *My most important goal for students is that they feel good about themselves and realize what they can do. I liked these activities, because they had these results.*

The standards are intended to promote just these sorts of outcomes. When a teacher has a "gut feeling" that something is working well, there is usually some basis to this feeling. As the NRC Science Standards state, "outstanding things happen in science classrooms today… because extraordinary teachers do what needs to be done *despite conventional practice* [emphasis added]." (1996, p. 12) Unfortunately, even an extraordinary teacher may not find support from traditional administrators, who complain that the classroom is too noisy or messy, or that somebody's guidelines are not being followed. Under these circumstances, standards can be very useful. It is usually easy to see how valuable innovations fit into a national framework of education reform that is also endorsed by state- and district-level authorities. Standards can be used to justify and enhance innovative educational programs whose value is already self-evident to teachers and students.

What the Standards Really Say

In order to justify work as meeting standards, it is necessary to know what the standards really say. In the remainder of this chapter, we summarize each of the five major standards documents listed at the beginning of the chapter, and show how the *Stuff That Works!* ideas are consistent with these standards. We provide some historical background for each of the standards, and look at the overall intent and structure before relating them to the *Stuff That Works!* materials. These sections should be used only as they are needed. For example, if you would like to use some of the ideas from this Guide, and are also required to meet the *National Science Education Standards*, then that section could be useful to you in helping you justify your work.

Standards for Technological Literacy: Content for the Study of Technology

In April 2000, the International Technology Education Association (ITEA) unveiled the *Standards for Technological Literacy*, commonly known as the *Technology Content Standards*, after extensive reviews and revisions by the National Research Council (NRC) and the National Academy of Engineering (NAE). In its general outlines, the new standards are based on a previous position paper, *Technology for All Americans* (ITEA, 1996). The latter document defined the notion of "technological literacy" and promoted its development as the goal of technology education.

A technologically literate person is one who understands "what technology is, how it is created, and how it shapes society, and in turn is shaped by society." (ITEA, 2000, p. 9) According to the *Standards*, familiarity with these principles is important not only for those who would pursue technical careers, but for all other students as well. They will need to know about technology in order to be thoughtful practitioners in most fields, such as medicine, journalism, business, agriculture, and education. On a more general level, technological literacy is a requirement for participation in society as an intelligent consumer and an informed citizen.

Given the importance of being technologically literate, it is ironic that technology barely exists as a school subject in the U.S., and is particularly hard to find at the elementary level. In a curriculum overwhelmingly focused on standardized tests, there seems to be little room for a new subject such as technology. To make matters worse, there is considerable confusion over what the term *technology* even means. Many in education still equate it with "computers." The *Standards* advocate for technology education based on a broad definition of "technology," which is "how humans modify the world around them to meet their needs and wants, or to solve practical problems." (p. 22)

The *Technology Content Standards* describe three aspects of developing technological literacy: learning *about* technology, learning to *do* technology, and technology as a theme for curriculum integration (pp. 4-9). To learn about technology, students need to develop knowledge not only about specific technologies (Standards 14 – 20), but also about the nature of technology in general (Standards 1 – 3), including its core concepts: **systems, resources, requirements, trade-offs, processes,** and **controls.** Resources include **materials, information,** and **energy,** while **modeling** and **design** are fundamental examples of processes (p. 33). Students learn to "do" technology by engaging in a variety of technological processes, such as **troubleshooting, research, invention, problem solving, use and maintenance, assessment** of technological impact, and, of course, **design** (Standards 8 – 13). Technology has obvious and natural connections with other areas of the curriculum, including not only math and science, but also language arts, social studies, and the visual arts.

The material in the *Stuff That Works!* guide *Mechanisms and Other Systems* offers numerous opportunities for learning the core concepts of technology. Household mechanisms are an excellent entry point because they are familiar items that are relatively simple to analyze and understand. The operation of a mechanism is usually based on the Law of the Lever, which is an expression of the Law of Conservation of Energy. Every mechanism is an example of a system, because its parts "work together to accomplish a goal." (p. 34) A mechanism's parts are made of materials, whose properties "determine whether it is suitable for a given application." Many common mechanisms are designed to serve as tools, another category of resources, that "extend human capabilities, such as holding, lifting, carrying, fastening." (p. 35)

By analyzing how simple mechanisms work, students develop an understanding of basic systems concepts: inputs and outputs, reversibility, subsystems, and parts vs. wholes. By asking what these mechanisms do, they encounter some of the ways in which tools extend human capabilities. In the course of modeling simple mechanisms in other materials, such as cardboard, rubber bands, and paper fasteners, some of the properties of these materials become obvious. For example, it is difficult to model a spring-type mousetrap using cardboard and rubber bands because cardboard is not as stiff or strong as metal. If the rubber band is stiff enough to produce the necessary snap action, it will probably cause the cardboard to bend instead of snapping.

In the course of these modeling activities, a variety of problems arise, which become opportunities to learn troubleshooting. For example, the parts of the cardboard mechanisms get caught on one another instead of moving freely. Instead of supplying the answer, the teacher might provide a focusing question: "Where, exactly, does that piece get hung up?" Similarly, there are many opportunities for research. A popular activity involves children in creating their own cardboard mechanisms that work the same way as "mystery mechanisms," whose moving parts are concealed. As children try to solve these problems, they ask questions like: "How can I make the input and output both go the same way?" This question provides an occasion for doing some research. The teacher might suggest that they look at how the same problem has been solved by the manufacturers of some familiar mechanisms, such as a pair of tweezers, a nutcracker, or a staple remover.

Where does technology education "fit" in the existing curriculum? The Technology *Standards* address this problem by claiming that technology can enhance other disciplines: "Perhaps the most surprising message of the *Technology Content Standards* ... is the role technological studies can play in students' learning of other subjects." (p. 6) We support this claim in the following sections, which draw the connections between *Mechanisms and Other Systems* and national standards in science, math, and English language arts.

Benchmarks for Science Literacy

There are two primary standards documents for science education: The American Association for the Advancement of Science (AAAS) *Benchmarks for Science Literacy* (1993) and the National Research Council (NRC) *National Science Education Standards* (1996). Unlike the *National Science Education Standards,* the *Benchmarks* provide explicit guidance for math, technology, and social science education, as well as for science. The *Benchmarks* draw heavily on a previous AAAS report, *Science for All Americans* (1989), which is a statement of goals and general principles rather than a set of standards. *Benchmarks* recast the general principles of *Science for All Americans* (SFAA) as minimum performance objectives at each grade level.

The performance standards in *Benchmarks* are divided among 12 chapters. These include three generic chapters regarding the goals and methods of science, math and technology; six chapters providing major content objectives for the physical, life, and social sciences, technology, and mathematics; and three generic chapters dealing with the history of science, "common themes," and "habits of mind." The last four chapters of *Benchmarks* provide supporting material, such as a glossary of terms and references to relevant research.

Recognizing that standards are necessary but not sufficient for education reform, the AAAS has also developed some supplementary documents to support the process of curriculum change. These include *Resources for Science Literacy: Professional Development* (1997), which suggests reading materials for teachers, presents outlines of relevant teacher education courses, and provides comparisons between the *Benchmarks,* the Math Standards, the Science Standards and the Social Studies Standards. A subsequent publication, *Blueprints for Science Reform* (1998) offers guidance for changing the education infrastructure to support science, math, and technology education reform. The recommendations in *Blueprints* are directed towards administrators, policy makers, parent and community groups, researchers, teacher educators, and industry groups. A subsequent AAAS document, *Designs for Science Literacy* (2001), provides examples of curriculum initiatives that are based on standards.

The *Benchmarks* present a compelling argument for technology education. The authors present the current situation in stark terms: "In the United States, unlike in most developed countries in the world, technology as a subject has largely been ignored in the schools." (p. 41) Then they point out the importance of technology in children's lives, its omission from the curriculum notwithstanding: "Young children are veteran technology users by the time they enter school.... [They] are also natural explorers and inventors, and they like to make things." (p. 44) To resolve this contradiction, "School should give students many opportunities to examine the properties of materials, to use tools, and to design and build things." (p. 44)

Like the Technology Standards, the *Benchmarks* identify design as a key process of technology and advocate strongly for first-hand experience in this area. "Perhaps the best way to become familiar with the nature of engineering and design is to do some." (p. 48) As children become engaged in design, they "begin to enjoy challenges that require them to clarify a problem, generate criteria for an acceptable solution, try one out, and then make adjustments or start over again with a newly proposed solution." (p. 49) These statements strongly support the basic approach of ***Stuff That Works!***, which is to engage children in analysis and design activities based on the technologies already familiar to them. Like ***Stuff That Works!***, the *Benchmarks* also recognize the back-and-forth nature of design processes, which rarely proceed in a linear, predictable sequence from beginning to end.

In the chapter "Common Themes," *Benchmarks* identifies several "big ideas" that recur frequently in science, mathematics, and technology, and are powerful tools for explanation and design. Two of these themes, **systems** and **models**, are at least as important in technology as in science, and both are squarely addressed by work with mechanisms and circuits. The section on systems begins, "One of the essential components of higher-order thinking is the ability to think about a whole in terms of the sum of its parts and, alternatively, about parts in terms of how they relate to one another and to the whole." (p. 262) The section goes on to point out that these ideas are difficult, and learned only through studying progressively more complex examples. In grades K-2, for example, "Students should practice identifying the parts of things and see how one part connects to and affects another..." (p. 264) By the end of grade eight, they should know that "the output from one part of a system can become the input to other parts." (p. 265) A simple mechanism is an excellent place to start exploring systems concepts, because the parts and their relationships are easily identifiable, as are the inputs and outputs. Simple mechanisms can serve as prototypes for making sense of more complex systems.

Another of the common themes is models, which are "tools for learning about the things they are meant to resemble." These include mathematical and conceptual models, as well as physical models. Of these, "physical models are by far the most obvious to young children, so they should be used to introduce the idea of models." (p. 266) As children design and make their own cardboard models of mechanisms, they quickly become aware that "a model of something is different from the real thing but can be used to learn something about the real thing" (p. 268). For example, in modeling a pair of scissors in oak tag, Annette Purnell's students realized that they could make the model *move* like a real pair of scissors, but they couldn't make it cut, because it was made of different materials. (See Chapter 4, p. 117.)

The importance of learning by doing is stressed in the chapter called "Habits of Mind." The section on "Manipulation and Observation" states, "Education for science literacy implies that students be helped to develop the habit of using tools, along with scientific and mathematical ideas and computation skills, to solve practical problems..." When "things don't work right... the problem can be diagnosed and the malfunctioning device fixed using ordinary troubleshooting techniques and tools." (p. 292) Toward those ends, the document presents the following benchmarks: "By the end of second grade, students should be able to make something out of paper, cardboard, wood, plastic, metal, or existing objects, that can actually be used to perform a task." (p. 292) "By the end of eighth grade, students should be able to inspect, disassemble, and reassemble simple mechanical devices and describe what the various parts are for." (p. 294) Here are compelling reasons for engaging children with mechanisms and circuits: these activities will provide them with the experience and confidence to make, analyze, and fix things.

Work with mechanisms engages students in exploring the characteristics of materials: "Young children should have many experiences in working with different kinds of materials, identifying and composing their properties and figuring out their suitability for different purposes." (p. 188) Children develop these skills as they try to model mechanisms.

The National Science Education Standards

In 1991, the National Science Teachers Association asked the National Research Council to develop a set of national science education standards. These standards were intended to complement the *Benchmarks*, which include math, technology, and social studies as well as natural science. The National Research Council (NRC) includes the National Academy of Sciences, which is composed of the most highly regarded scientists in the country. Over the course of the next five years, the NRC involved thousands of scientists, educators, and engineers in an extensive process of creating and reviewing drafts of the new science standards. The results were published in 1996 as the *National Science Education Standards* (NSES).

Who is the audience for standards? The conventional view is that standards outline what students should know and be able to do, and that teachers are accountable for assuring that their students meet these guidelines. The NSES take a much broader approach, looking at the whole range of systemic changes needed to reform science education. The document is organized into six sets of standards. Only one of the six, the "Science Content Standards," talks directly about what children should learn through science education. The other five address other components of the education infrastructure, including classroom environments, teaching methods, assessment, professional development, administrative support at the school and district levels, and policy at the local, state, and national levels.

Collectively, these standards outline the roles of a large group of people on whom science education depends: teachers, teacher educators, staff developers, curriculum developers, designers of assessments, administrators, superintendents, school board members, politicians, informed citizens, and leaders of professional associations. If an administrator or school board member were to ask a teacher, "What are you doing to address the *National Science Education Standards*?" the teacher would be fully justified in responding, "What are *you* doing to meet them?"

One message that recurs frequently in the NSES is that teachers must be regarded as professionals, with a vital stake in the improvement of science education and an active role "in the ongoing planning and development of the school science program." (p. 50) More specifically, they should "participate in decisions concerning the allocation of time and other resources to the science program." (p. 51) The Standards explicitly reject the reduction of teachers to technicians or functionaries who carry out somebody else's directives. "Teachers must be acknowledged and treated as professionals whose work requires understanding and ability." The organization of schools must change too: "School leaders must structure and sustain suitable support systems for the work that teachers do." (p. 223)

Teachers should also play a major role in deciding and/or designing the science curriculum. The *Standards* call for teachers to "select science content and adapt and design curricula to meet the needs, interests, abilities and experiences of students." Although teachers set the curriculum initially, they should remain flexible: "Teaching for understanding requires responsiveness to students, so activities and strategies are continuously adapted and refined to address topics arising from student inquiries and experiences, as well as school, community and national events." (p. 30) Not only teachers, but also students, should play a major role in curriculum planning. The Teaching Standards make this point explicit: "Teachers [should] give students the opportunity to participate in setting goals, planning activities, assessing work and designing the environment." (p. 50)

More specifically, Content Standard E, "Science and Technology," strongly supports the approach of ***Stuff That Works!:*** "Children's abilities in technological problem solving can be developed by firsthand experience in tackling tasks with a technological purpose. They can also study technological products and systems in their world—zippers, coat hooks, and can openers... They can study existing products to determine function and try to identify problems solved, materials used and how well a product does what it is supposed to do... Tasks should be conducted within immediately familiar contexts of the home and school." (p. 135)

The Science Standards do not make the distinction between design and inquiry as sharply as do the Technology Standards: "Children in grades K-4 understand and can carry out design activities earlier than they can inquiry activities, but they cannot easily tell the difference between the two, nor is it important whether they can." (p.135) Thus, many of the abilities and concepts needed to meet the standard "Science as Inquiry" are also developed through design. These include: "Ask a question about objects... in the environment"; "plan and conduct a simple investigation"; "employ simple equipment and tools to gather data"; and "communicate investigations or explanations." (p. 122)

The material in *Mechanisms and Other Systems* is of particular relevance to the K-12 Content Standards, "Unifying Concepts and Processes." Two of the five unifying themes are "systems, order and organization" and "form and function." As already mentioned, either a mechanism or a circuit can serve as a prototype for developing the concept of a system, which the NSES defines as "an organized group of related components or objects that form a whole." (p. 116) Similarly, examination of a mechanism, and close analysis of how it works, can be a prototype for learning that "the form or shape of an object or system is frequently related to use, operation or function." (p. 119)

The material in *Mechanisms and Other Systems* also addresses Content Standard B, "Physical Science," for grades K-4. Sorting and classifying mechanisms, for example, is an obvious way to discover the "properties of objects and materials" and the "similarities and differences of the objects." As they look at how simple mechanisms operate, children develop their own understanding of the "position and movement of objects." (p. 125) Their work with electric switches and other control devices helps them "begin to understand that phenomena can be observed, measured and controlled in various ways." (p. 126)

Principles and Standards for School Mathematics

The first of the major standards documents, *Curriculum and Evaluation Standards for School Mathematics*, was published in 1989 by the National Council of Teachers of Mathematics (NCTM). Additional standards for teaching and assessment were published in 1991 and 1995, respectively. In 2000, the NCTM released a new document, *Principles and Standards for School Mathematics*, intended to update and consolidate the classroom-related portions of the three previous documents. Some of the major features of the new volume, different from the prior version, are the addition of the Principles, the division of the standards into the categories "Content" and "Process," and the inclusion of a new process standard called "Representation."

The new NCTM document acknowledges the limitations of educational standards: "Sometimes the changes made in the name of standards have been superficial or incomplete... Efforts to move in the direction of the original NCTM Standards are by no means fully developed or firmly in place." (pp. 5-6) In spite of this candid assessment, the authors remain optimistic about the future impact of standards. Their goal is to provide a common framework for curriculum developers and teachers nationwide. If all schools follow the same standards, then teachers will be able to assume that "students will reach certain levels of conceptual understanding and procedural fluency by certain points in the curriculum." (p. 7)

The NCTM *Principles and Standards* begin by presenting the six sets of principles, which are the underlying assumptions for the standards. Some of these principles are common to the other standards documents: that there should be high expectations of all students, that the goal of learning is deep understanding, and that assessment should be integrated with curriculum. Other principles underscore the need to learn from cognitive research. More than in any other field, there has been extensive research into how students learn mathematics, and this research base is reflected in the *Principles*. For example, the "Curriculum Principle" calls for coherent sets of lessons, focused collectively on one "big idea." Similarly, the "Teaching Principle" specifies that teachers must be aware of students' cognitive development. The "Learning Principle" cites research on how learning can be most effective.

The standards themselves are organized into two categories: Content Standards and Process Standards. The former describe what students should learn, in the areas of Number and Operations, Algebra, Geometry, Measurement, and Data Analysis and Probability. The Process Standards discuss how students should acquire and make use of the content knowledge. The subcategories are Problem Solving, Reasoning and Proof, Communication, Connections, and Representation. Unlike the earlier NCTM document, the new version uses all the same standards across all of the grade levels, from K through 12. In this way, the NCTM is advocating for a carefully structured curriculum, which builds upon and extends a few fundamental ideas systematically across the grades. Readers may be surprised to find an Algebra Standard for grades K-2, or a Number and Operations Standard for grades 9-12.

Stuff That Works! units and activities offer rich opportunities for fulfilling a key ingredient of the NCTM standards: learning and using mathematics in context. The Process Standard called "Connections" makes it clear that mathematics should be learned by using it to solve problems arising from "other subject areas and disciplines" as well as from students' daily lives."

(p. 66) *Stuff That Works!* fulfills this standard in two fundamental respects: it provides mathematics connections with another subject area, technology, and it uses artifacts and issues from everyday life as the source of material for study. The mathematics students learn is drawn from all of the Content Standards, as well as all of the Process Standards except for Reasoning and Proof.

Mechanisms and Other Systems engages students in basic learning about spatial relationships. Students sketch simple mechanisms in their open and closed positions, or try to draw the basic topographical relationships of simple circuits. Often, these representations become a form of communication about how to make things or about how they work. Modeling a mechanism is an engaging activity that requires close attention to geometric relationships and, often, measurement as well. If the model does not work the same way as the original mechanism, it may indicate that the parts are not of the proper shapes or the correct proportions, and that calls for problem solving.

Sorting and classifying everyday objects are very popular starting activities in *Mechanisms and Other Systems.* These activities prepare the way for the more formal methods of pattern handling known as algebra. The NCTM strongly recommends that these basic ideas about patterns be developed with very young children. The Algebra Standard for grades K-2 calls for pattern finding and pattern recognizing activities, such as classifying and sorting, and identifying "the criteria [students] are using as they sort and group objects." Basic classifying activities are designed to "help students develop the ability to form generalizations." (p. 91) As part of *Mechanisms and Other Systems,* students sort mechanisms, switches, and other controls, and ask other students to "guess what our categories were" just by looking at the objects in each group.

Standards for the English Language Arts

By 1991, it had become clear that standards would be produced for all of the major school subjects. Fearful that English language standards might be produced without a firm basis in research and practice, two major professional organizations requested Federal funding for their own standards effort. The following year, the Department of Education awarded a grant for this purpose to the Center for the Study of Reading at the University of Illinois, which agreed to work closely with the two organizations, the National Council of Teachers of English (NCTE) and the International Reading Association (IRA). This effort culminated in the 1996 publication of the *Standards for the English Language Arts* by the NCTE and IRA. These ELA Standards are now widely accepted for their clear, concise outline of English language education.

The ELA *Standards* adopt an unusually comprehensive view of "literacy," much broader in its scope than the traditional definition of "knowing how to read and write." (p. 4) Literacy also includes the ability to think critically, and encompasses oral and visual, as well as written communication. Recognizing that these forms of language "are often given limited attention in the curriculum," the *Standards* outline the variety of means used to convey messages in contemporary society:

> "Being literate in contemporary society means being active, critical, and creative users not only of print and spoken language, but also of the visual language of film and television, commercial and political advertising, photography, and more. Teaching students how to interpret and create visual texts such as illustrations, charts, graphs,

electronic displays, photographs, film and video is another essential component of the English language arts curriculum." (pp. 5-6)

According to the ELA *Standards*, there are three major aspects to language learning: **content**, **purpose**, and **development**. Content standards address only *what* students should learn, but not why or how: "Knowledge alone is of little value if one has no need to – or cannot – apply it." The *Standards* identify four purposes for learning and using language: "for obtaining and communicating information, for literary response and expression, for learning and reflection, and for problem solving and application." (p.16) Purpose also figures prominently in the third dimension of language learning, development, which describes *how* students acquire this facility. "We learn language not simply for the sake of learning language; we learn it to make sense of the world around us and to communicate our understanding with others." (p. 19)

Of course, purpose and motivation vary from one situation to another. The authors of the *Standards* make this point, too, in their discussion of "context." "Perhaps the most obvious way in which language is social is that it almost always relates to others, either directly or indirectly: we speak to others, listen to others, write to others, read what others have written, make visual representations to others and interpret their visual representations." Language development proceeds through the practice of these communication skills with others: "We become participants in an increasing number of language groups that necessarily influence the ways in which we speak, write and represent." While language development is primarily social, there is an individual dimension as well: "All of us draw on our own sets of experiences and strategies as we use language to construct meaning from what we read, write, hear, say, observe, and represent." (p. 22)

How does this broad conception of literacy and its development relate to daily classroom practice? The authors recognize that the ELA *Standards* may be in conflict with the day-to-day demands placed on teachers. "They may be told they should respond to the need for reforms and innovations while at the same time being discouraged from making their instructional practices look too different from those of the past." Among those traditional practices are the use of standardized tests, "which often focus on isolated skills rather than contextualized learning." Prescribed texts and rigid lesson plans are further barriers to reform, because they tend to preclude "using materials that take advantage of students' interests and needs" and replace "authentic, open-ended learning experiences." (p. 7) Another problem is "the widespread practice of dividing the class day into separate periods [which] precludes integration among the English language arts and other subject areas." (p. 8) Taken seriously, these standards would lead to wholesale reorganization of most school experiences.

This introductory material sets the stage for the twelve content standards, which define "what students should know and be able to do in the English language arts." (p. 24) Although these are labeled "content" standards, "content cannot be separated from the purpose, development and context of language learning." (p. 24) In a variety of ways, the twelve standards emphasize the need to engage students in using language clearly, critically and creatively, as participants in "literacy communities." Within these communities, students sometimes participate as *receivers* of language—by interpreting graphics, reading and listening and—and sometimes as *creators*—by using visual language, writing, and speaking.

Some teachers have used the ***Stuff That Works!*** activities and units primarily to promote language literacy, rather than for their connections with math or science. Technology activities offer compelling reasons for children to communicate their ideas in written, spoken, and visual form. In early childhood and special education classrooms, teachers have used *Stuff That Works!* to help children overcome difficulties in reading and writing, because it provides natural and non-threatening entry points for written expression. In the upper elementary grades, *Stuff That Works!* activities offer rich opportunities for students to want to use language for social purposes. Several characteristics of *Stuff That Works!* contribute to its enormous potential for language learning and use:

- Every unit begins with an extensive group discussion of what terms mean, how they apply to particular examples, how to categorize things, and/or what problems are most important.
- The activities focus on artifacts and problems that engage children's imaginations, making it easy to communicate about them. Teachers who use *Stuff That Works!* usually require students to record their activities and reflections in journals.

For each of the *Stuff That Works!* topics, the opening activity is a scavenger hunt or brainstorming session.

In a brainstorming session, students think of the examples, list them, and then try to make sense of them. Often, the teacher starts the discussion by asking the students to define a word. These discussions can be rich opportunities to explore and inquire about language.

For example, at the beginning of a unit on mechanisms, Mary Flores asked her special education students, "What is a mechanism?" One of Mary's students said, "I see the word *mechanic*." Another said that it sounds like the word *mechanical*. A student from another group said, "We are mechanisms because we move around." (See Chapter 4, p. 128.) The students in this class were "draw[ing] on their prior experience, their interactions with other readers and writers [and] their knowledge of word meaning and of other texts," to make sense of this new word (ELA Standard #3, p. 31).

Many special education students have very low self-esteem and are deeply frustrated by the difficulties they experience in learning to read and write. By focusing on tangible and interesting artifacts, *Stuff That Works!* activities offer unusual opportunities to overcome some of these barriers. Faced with a group who were unwilling to write at all, Kathy Aguiar asked them to talk about and draw pictures of various mechanical devices, and to make a one-word label showing the "control." Before long, they were writing full sentences describing how they thought these devices worked. (See Chapter 4, p. 121.) These students were learning "to adjust their use of spoken, written and visual language to communicate effectively." (ELA Standard #4, p. 33)