FACT SHEETS

HOW WE LEARN, HOW WE TEACH: *SYNTHESES OF THE RESEARCH*

Ohio Mathematics and Science Coalition

OMSC

NCREL

FACT SHEETS

HOW WE LEARN, HOW WE TEACH: *SYNTHESES OF THE RESEARCH*

Prepared by
Chris Otto and Arie van der Ploeg
North Central Regional Educational Laboratory
for the Ohio Mathematics and Science Coalition

NCREL

North Central Regional Educational Laboratory
1120 East Diehl Road, Suite 200
Naperville, Illinois 60563-1486
(800) 356-2735, (630) 649-6500
www.ncrel.org

OMSC

Ohio Mathematics and
Science Coalition
22800 Cedar Point Road
Cleveland, Ohio 44142
(440) 962-3038
www.oai.org/omsc

This work was produced in whole or in part with funds from the U.S. Department of Education under Eisenhower grant numbers R168R50003 and R319A000010 and from the Ohio Mathematics and Science Coalition. The content does not necessarily reflect the position or policy of the Department of Education, nor does mention or visual representation of trade names, commercial products, or organizations imply endorsement by the federal government.

Contents

FOREWORD

For centuries, scientists and researchers have used the scientific method to solve complex problems in physics, astronomy, and medicine. This concept of making decisions using data collected through observation and experimentation is just beginning to take hold in education. Some have termed "data-driven decision making" the new mantra of education.

With this in mind, the Ohio Mathematics and Science Coalition (OMSC) formed a partnership with the North Central Regional Educational Laboratory (NCREL) to find out what mathematics and science education looks like today in the state. We then compared the Ohio data to what education looks like around the United States and the world in order to help determine what Ohio needs to do to move to the forefront of educational excellence.

Founded in 1995, OMSC is an advocacy group composed of individuals from the education, business, and public sectors working with the common goal of revitalizing and improving mathematics, science, and technology education from preschool to beyond graduate school. Its mission is to facilitate collaboration for continuous and sustainable improvement in these areas for Ohio's nearly two million students. OMSC has designed a carefully planned sequence of activities to achieve broad consensus on the goals and attributes of a world-class system of mathematics and science education in Ohio and a continuous improvement plan to develop that system.

OMSC is committed to improvement through systemic change. Systemic change is an effective way to approach the complex structures and issues facing the state of Ohio and includes:

- Creating a common vision of the central purposes and goals of mathematics and science education
- Achieving coherence and consistency in state and local policies and practices at every level
- Redefining roles and relationships of all involved in the education of children
- Bringing district and state leadership together to work to articulate the common vision and to design the appropriate policies that foster commitment and the capacity to attain it

A Visioning Council was established to oversee the creation of that common vision. It is a partnership of representatives from the Office of the Governor, Ohio Department of Education, Ohio Board of Regents, Ohio Business Roundtable, NASA Glenn Research Center Office of External Affairs, Air Force Research Laboratory at Wright-Patterson Air Force Base, and OMSC. In 1997, the Visioning Council supported OMSC's plan to encourage the development and implementation of a system for the continuous improvement of mathematics and science education in Ohio.

OMSC asked NCREL, one of the ten regional educational laboratories, to assess both the status of mathematics and science education in Ohio and Ohio's expectations for school mathematics and science education. As part of that assessment work, 25 of

Ohio's best teachers, all National Board-certified or recipients of Presidential Awards in mathematics or science teaching, were brought together in November 1999 to share their views at the OMSC Teacher Colloquium. Their discussions illuminated not only common goals but common problems across the broad spectrum of Ohio's schools.

With this insight and the best of available research in hand, OMSC is developing a set of guiding principles, goals, and actions that can serve as a framework for mathematics and science education for all Ohioans in the 21st century. Expert synthesis of the information on the science side will be written by Peter Hewson, professor of science education at the University of Wisconsin-Madison. On the mathematics side, a similar effort will be undertaken by Michael Battista, professor of mathematics education at Kent State University.

The Fact Sheets included here are the first step in creating these consensus principles. We view this activity as a dynamic one, where the statements will grow in number and in detail as consensus is achieved. The necessary educational changes will come incrementally, on many fronts, over a significant period of time.

The recent Third International Mathematics and Science Study indicates that the United States lags behind many nations in mathematics and science education. We need to develop standards-based education where the curriculum, assessments, and professional development of teachers are aligned; to increase substantially the percentage of graduates who complete challenging, high-level mathematics and science courses; and to improve and increase both access and achievement for all students.

From the educators who teach students, the businesses that employ them, and the parents who encourage and support them, to the citizens who will share society with them and the government policymakers who bring unity and direction to overall education—everyone is affected by mathematics, science, and technology education. Our economic well-being is increasingly driven by technology, and our future workforce must be adequately prepared. Mathematics and science education directly affects our ability to understand and address environmental, medical, and other critical social issues, and everyone must work to improve it. Now is the time to begin and for each Ohioan to carry his or her share of the load.

William G. Steenken
Chair
Ohio Mathematics and Science Coalition

Acknowledgments

These Fact Sheets were prepared for the Ohio Mathematics and Science Coalition (OMSC) by staff of the North Central Regional Educational Laboratory (NCREL). The intent of the project was to gather and summarize the best available research on teaching and learning mathematics and science, and juxtapose the data against the current context and conditions in the state of Ohio. By connecting the reader with seminal, original educational research, we expect these documents to provide a clear and factual foundation for making sound decisions in educational practice.

Arie van der Ploeg, a senior program associate with NCREL's Evaluation and Policy Information Center, directed this data-driven approach to summarizing the issues. He brings extensive experience and knowledge of data analysis and educational policy issues. His work focuses primarily on student and school productivity measurement, demographics, and survey measures—particularly as they apply to school improvement.

Anne Burgunder, a national consultant, workshop presenter, author, and mathematics curriculum specialist provided data and Ohio-specific information for many of the Fact Sheets. For the past three years, she has served as a consultant to the Hebrew Academy of Toledo and is widely regarded as a teacher's teacher.

Valuable contributions came from many NCREL staff members, most notably Nancy Berkas, program associate for the North Central Mathematics and Science Consortium (NCMSC); Barbara Youngren, NCREL senior program associate; Dr. Gilbert Valdez, director of NCMSC and associate director of NCREL; and Arlene Hough and the NCREL Resource Center staff.

The series of Fact Sheets begins with an examination of student learning adapted from the 1999 book *How People Learn: Brain, Mind, Experience, and School* by John Bransford, Ann Brown, and Rodney Cocking, with permission from the National Academy Press.

The authors also gratefully acknowledge the work of SciMathMN, the Minnesota Science Teachers Association, and Minnesota Council of Teachers of Mathematics. Their collaborative efforts produced the K-12 Science and Mathematics Frameworks, which served as an invaluable resource and provided a natural stepping-stone in the development of this project.

Freelance writer Chris Otto put it all together to give the text its final shape. Design and layout were done by NCREL's Chris Sabatino, with desktop publishing by Melissa Chapko, editing by Cinder Cooper and Lenaya Raack, and production by Stephanie Blaser.

Introduction

Schools across the U.S. are under increasing pressure to improve student achievement; Ohio's schools are no different. To truly respond to the calls for better performance, we must examine how students learn and how teachers teach. We must take a critical look at our schools, our classrooms, our materials, our techniques, and our expectations.

Gathering some of the most respected research on teaching and learning mathematics and science, this series of Fact Sheets compares and contrasts the best available data with the current state of education in Ohio. By bringing critical, often overlooked research to the forefront, the Fact Sheets provide a fresh and authoritative look at the challenges facing Ohio's schools while delivering a clear and factual foundation for making sound decisions about changing teaching and learning.

In any serious effort to make schools better, we must examine every aspect of the schools and the processes of teaching and learning to find areas that can be changed, upgraded, and improved. The topics addressed in these Fact Sheets help illuminate how learning takes place, how teachers are going about their jobs, and how both could be done differently and, perhaps, more successfully. This understanding can help schools and communities begin a meaningful, informed dialogue about what is happening in their own classrooms and how it can be changed. It can help refocus discussions with local decision makers on the issues in mathematics and science learning that really matter—issues such as teacher quality; standards; and collaborative, hands-on learning.

There is no single recipe for improving all schools, but the information gathered here will point teachers, parents, and administrators in a direction that, perhaps, they did not see previously, a direction that may lead to the making of powerful changes in teaching and learning.

"School should be less about preparation for life, and more like life itself."

John Dewey

"Scarce data and sequential execution are what numbers and equations are optimized for. The new maths come into their own when data become cheap and abundant."

James Bailey, *After Thought*

The Student

How Students Learn

The last decade has brought significant advances in scientific research on intellectual development. We know more about the human mind and brain than ever before, yet the research has had seemingly little impact on how schools educate children. Knowledge of how the brain works and develops is only relevant to education if the information is used to improve education.

What does the research tell us about how students learn? How can schools use this information to do better? Are there more efficient ways to teach students what they need to know? How do we provide them with more effective intellectual tools and learning strategies they will need after leaving the classroom?

School Versus Life

The ultimate goal of schooling is to prepare students for life beyond graduation—higher education and the workplace. However, the environment created by the culture of our schools may be compromising that goal by starkly contradicting the environment outside of school.

In the book *How People Learn: Brain, Mind, Experience, and School (1999),* John Bransford, Ann Brown, and Rodney Cocking summarize modern research into learning and the role of schools. The book presents three major discrepancies between the culture that dominates schools and that of today's workplace:

- Individual work and achievement is stressed at school, while in the workplace, it is rare that individuals succeed without collaboration from others. For instance, no individual alone can pilot a ship,[1] make significant scientific discoveries in a genetics laboratory,[2] or make critical decisions in a hospital emergency room.[3] These, and most other professions, require teamwork, input and cooperation from a number of people, efficient communication, and coordination of knowledge and effort.
- In the workplace, tools are used to solve problems and get work done faster, more efficiently, and more conveniently. School emphasizes "mental work." People in the workplace can work efficiently and almost error-free with the use of tools such as calculators, computers, and software.[4] New technologies have made it possible for students in school to use those same tools, but they don't.
- School emphasizes abstract reasoning while the real world presents contextual situations.[5] Reasoning can be improved when abstract problems are applied in a context that means something to students.[6] Consider the example set by problem-based learning in medical schools. The opportunity for first-year medical students to engage in actual case-based problem solving leads to a greater ability to diagnose and understand medical problems than do opportu-

nities to learn in a typical lecture-based medical course.[7]

Understanding Learning

School, particularly in mathematics, typically stresses repetition and practice.[8] As John Dewey pointed out, the culture of schools fails to emulate that of the workplace, even though it should.

To give students a school environment that more effectively prepares them for life beyond the classroom, the current environment must be reexamined and changed. To do so, it is important for educators to better understand thinking, learning, and teaching, as well as the demands of today's society and the needs of tomorrow's leaders.

These issues are summarized in separate Fact Sheets, under the following titles:

Experts and Novices

Learning and Transfer

Children as Students

The Mind and Brain

Changing Needs, Changing Goals

Schools have been teaching the same basic skills for decades, even as the world around them has changed drastically. Reform efforts have focused on teaching reading, writing, and arithmetic more efficiently; however, it is no longer enough. Education now must do more.

In the last 30 years alone, computers have altered society and the workplace in ways no one could have foreseen. Skill sets for meaningful, productive careers demand more than just factual knowledge—more than just reading, writing, and calculating. Information management and problem solving are critical skills necessary for survival in today's workplace. Knowledge of mathematical equations, scientific formulas, and definitions is not nearly as useful as attaining an understanding of math and science concepts and the ability to frame and ask questions about them.

School traditionally has been a place for students to acquire knowledge. With the rapid growth of the Internet, the amount of knowledge and information available today is staggering. No significant portion can be learned or taught. In the 21st century, students will be better served if school is a place where they can be taught to manage information, acquire what is relevant, and apply it to solve problems. For teachers, this goal is practical and entirely achievable.

Endnotes

1. L. B. Resnick, *Education and Learning to Think,* National Academy Press, Washington, DC, 1987.
2. K. Dunbar, "Problem Solving Among Geneticists," Paper prepared for the Committee on Developments in the Science of Learning for the "Sciences of Science Learning: An Interdisciplinary Discussion," 1996.
3. V. L. Patel, D. R. Kaufman, and S. A. Magder, "The Acquisition of Medical Expertise in Complex Dynamic Environments," in K. A. Ericsson (Ed.), *The Road to Excellence: The Acquisition of Expert Performance in the Arts and Sciences, Sports and Games,* Erlbaum, Mahwah, NJ, 1996.
4. P. Cohen, *A Calculating People: The Spread of Numeracy in Early America,* University of Chicago Press, Chicago, 1983; A. D. Schliemann and N. M. Acioly, "Mathematical Knowledge Developed at Work: The Contribution of Practice Versus the Contribution of Schooling," *Cognition and Instruction,* 6, pp.185-222, 1989; H. A. Simon, "On the Development of the Processes," in L. B. Resnick and L. E. Klopfer (Eds.), *Information Processing in Children,* ASCD Books, Alexandria, VA, 1972; D. A. Norman, *Things That Make Us Smart: Defending Human Attributes in the Age of the Machine,* Addison-Wesley, New York, 1993.
5. Resnick, 1987.
6. P. C. Wason and P. N. Johnson-Laird, *Psychology of Reasoning: Structure and Content,* Harvard University Press, Cambridge, MA, 1972.
7. C. E. Hmelo, "Problem-based Learning: Development of Knowledge and Reasoning Strategies," in *Proceedings of the Seventeenth Annual Conference of the Cognitive Science Society,* Erlbaum, Pittsburgh, PA, 1995.
8. See "The Classroom: Homework" and "The Classroom: Classwork."

"As soon as you write an equation, it is wrong, because reducing a complex reality to an equation is just too simplistic a view of things. Large parallel computers, with large amounts of memory, may allow us to develop an entirely new sort of physics where . . . we can just store in the computer the facts. Then we can extrapolate and we can predict. That's what physics is about: extrapolating and predicting."

A. Tarantola[1]

The Student

Experts and Novices

To better understand the factors involved in learning, it is useful to take a look at people who seem to have learned the most. What are the fundamental differences between experts and novices? We know that novices do not become experts simply by virtue of length of service or even hard work, but why not? What do experts know or do differently?

- Experts consistently notice features and patterns of information that novices do not notice. In a study of chess players with varying levels of experience, chess masters saw moves and strategies that lesser players did not see.[2] Similarly, a study of teachers revealed that after observing videotaped classroom lessons, more experienced teachers had very different understandings of the events they were watching than did novice teachers.[3]
- Experts have a great deal of content knowledge that is organized in ways that reflect deep understanding of the subject. For example, physics experts organize their problem-solving ideas around major principles that are applicable to the problem, while beginners—even competent beginners—rely more on manipulating memorized equations.[4]
- Experts have not only acquired knowledge, they seem to have developed an efficient, mental "filing system." They don't have to search through everything they know to retrieve knowledge relevant to a particular task. The knowledge has been "conditionalized"—it includes a specification of the contexts in which it is useful.[5]
- Experts are able to retrieve important aspects of their knowledge with relatively little effort. This doesn't mean experts can do things faster than novices. In fact, because experts take the time to understand the problem fully, rather than hurry into assigning pat answers, they may take longer.[6] The amount of information a person can attend to at any one time is limited.[7] Ease of processing gives a person more capacity to attend to other tasks. For instance, novice readers are too focused on decoding words to devote attention to the task of understanding what they are reading.[8]
- Though experts know their disciplines thoroughly, there is no guarantee that they can teach it to others. Experts easily lose perspective of what is easy and what is hard. To teach well, an expert must not only have mastery or advanced knowledge in his or her discipline, he or she must also be an expert in teaching.[9]
- Experts have different levels of flexibility in their approach to new situations. Some expert chefs excel at following a fixed recipe, while others are able to improvise with equal or even better results.[10] Experts step back from their first impressions of a problem and question their own relevant knowledge.

- Not only do experts apply their expertise to solving problems, they also question whether the problem as presented is the best way to begin. The business world likes to call this "thinking outside the box." Experts don't simply try to do the same things efficiently, they try to do things better.

There is much to be learned from the expert learning model, but we cannot assume that by simply exposing students to the model, they will learn effectively. What students learn depends heavily on what they already know.

By the same token, not all teachers will become experts either. The ones who do, however, should be given the space and time to do what they do best. The ones who don't should be given the same opportunity to do what they do better.

Adapted from J. D. Bransford, A. L. Brown, and R. R. Cocking, *How People Learn: Brain, Mind, Experience, and School*, National Academy Press, Washington, DC, 1999.

Endnotes

1. Quoted in J. Bailey, *After Thought: The Computer Challenge to Human Intelligence,* Basic Books, New York, NY, 1996.
2. A. D. deGroot, *Thought and Choice in Chess,* Mouton, The Hague, The Netherlands, 1965.
3. D. S. Sabers, K. S. Cushing, and D. C. Berliner, "Differences Among Teachers in a Task Characterized by Simultaneity, Multi-dimensionality, and Immediacy," *American Educational Research Journal, 28*(1), pp. 63-88, 1991.
4. M. T. H. Chi, P. J. Feltovich, and R. Glaser, "Categorization and Representation of Physics Problems by Experts and Novices," *Cognitive Science, 5*, pp. 121-152, 1981.
5. H. A. Simon, "Problem Solving in Education," in D. T. Tuma and R. Reif (Eds.), *Problem Solving and Education: Issues in Teaching and Research,* Erlbaum, Hillsdale, NJ, 1980; R. Glaser, "Expert Knowledge and Processes of Thinking," in D. F. Halpern (Ed.), *Enhancing Thinking Skills in the Sciences and Mathematics,* Erlbaum, Hillsdale, NJ, 1992.
6. J. Getzels and M. Csikszentmihalyi, *The Creative Vision,* Wiley, New York, 1976.
7. G. A. Miller, "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity to Process Information," *Psychological Review, 63*, pp. 81-87, 1956.
8. D. Laberge and S. J. Samuels, "Toward a Theory of Automatic Information Processing in Reading," *Cognitive Psychology, 6*, pp. 293-323, 1974.
9. L. Shulman, "Those Who Understand: Knowledge Growth in Teaching," *Educational Researcher, 15*(2), pp. 4-14, 1986; and "Knowledge and Teaching: Foundations of the New Reform," *Harvard Educational Review, 57*(1), pp. 1-22, 1987.
10. G. Hatano and K. Inagaki, "Two Courses of Expertise," in H. Stevenson, H. Azuma, and K. Hakuta (Eds.), *Child Development and Education in Japan,* W. H. Freeman, New York, 1986.

The Student

"While it is not new to include thinking, problem solving, and reasoning in some students' school curriculum, it is new to include it in everyone's curriculum."

Lauren and Daniel Resnick

Learning and Transfer

In the context of education, transfer is "the ability to extend what has been learned in one context to new contexts."[1] Learning anything is of limited value if it cannot be transferred into a useful, meaningful context.

The following are major factors influencing transfer:

- ***Mastery of the content:*** In studies of whether knowledge of computer languages transfers to other areas of thinking and problem solving, findings show that the more that is learned about a subject, the more likely it is to be transferred into other contexts.[2]
- ***Understanding versus memorizing:*** Students who only memorize facts have little basis for approaching problems with sound reasoning. For instance, students who have only been instructed to memorize the physical properties of veins and arteries have difficulty answering questions about how structure relates to function, such as "Why are arteries elastic?"[3]
- ***Learning time:*** Students need to be given sufficient time to learn concepts and process new information. Third graders typically take about 15 seconds to integrate pictorial and verbal information. When given only 8 seconds, mental integration does not occur.[4] Learning can't be rushed, nor should it move too slowly. When activities are stretched out for a long period of time, engagement often gives way to boredom.
- ***Motivation to learn:*** People are motivated to solve problems and achieve competence.[5] Rewards and punishments affect behavior, but people work hard for intrinsic reasons as well.[6] Students of all ages are more motivated when they can see the usefulness of what they are learning, particularly when they believe it will affect others in their community. When asked to name highlights of the previous school year, a group of inner-city sixth graders frequently mentioned projects that involved hard work but had strong social consequences, such as tutoring younger children or designing blueprints for playhouses.[7]
- ***Real-world relevance:*** Skills and knowledge must be extended beyond the narrow scope in which they are learned. Knowing how to solve a math problem in school may not transfer to solving math problems in other situations. A group of homemakers did very well at making supermarket best-buy calculations despite doing poorly on equivalent school-like paper-and-pencil math problems.[8] In a separate study, Brazilian street children performed math when making sales on the street, but they couldn't solve similar problems presented in a school context.[9]
- ***Prior understanding:*** Even on the first day of class, students bring relevant knowledge of the subject matter; however, they may have difficulty with

teaching that conflicts with that knowledge. For example, students bring basic knowledge of the human and animal need for food to biology class. When studying the role of soil and photosynthesis in plant growth, some students have misconceptions such as soil is the plant's food, plants get food from their roots and store it in their leaves, or chlorophyll is the plant's blood. If the teacher does not take these misconceptions into account, address them, and discuss why they are incorrect, students can be easily left with an incorrect understanding.[10]

For learning to be truly effective, students must develop a sense of when their knowledge can be used. Failure to learn something often occurs because students have little or no idea when they are supposed to use the knowledge they have been taught. For example, if a math student sees no relevance to negative integers and has no understanding of how they might apply to anything outside math class, learning may occur at some level, but transfer most likely will not.

The knowledge needed for good thinking is acquired only through the processes of thinking. Knowledge must be used generatively—it needs to be called up again and again to link to, interpret, and explain new information.[11]

Adapted from J. D. Bransford, A. L. Brown, and R. R. Cocking, *How People Learn: Brain, Mind, Experience, and School*, National Academy Press, Washington, DC, 1999.

Endnotes

1. J. P. Byrnes, *Cognitive Development and Learning in Instructional Contexts,* Allyn and Bacon, Boston, MA, 1996.
2. D. Klahr and S. M. Carver, "Cognitive Objectives in a LOGO Debugging Curriculum: Instruction, Learning, and Transfer," *Cognitive Psychology 20*(3), pp. 362-404, 1988; and J. Littlefield, V. Delclos, S. Lever, K. Clayton, J. Bransford, and J. Franks, "Learning LOGO: Method of Teaching, Transfer of General Skills, and Attitudes Toward School and Computers," in R. E. Mayer (Ed.), *Teaching and Learning Computer Programming,* Erlbaum, Hillsdale, NJ, 1988.
3. J. D. Bransford, B. S. Stein, N. J. Vye, J. J. Franks, P. M. Auble, K. J. Mezynski, and G. A. Perfetto, "Differences in Approaches to Learning: An Overview," *Journal of Experimental Psychology: General, 3,* pp. 390-398, 1983; and J. M. Bransford and B. S. Stein, *The IDEAL Problem Solver* (2nd ed.), Freeman, New York, 1993.
4. K. Pezdek and L. Miceli, "Lifespan Differences in Memory Integration as a Function of Processing Time," *Developmental Psychology, 18,* pp. 485-490, May, 1982.
5. R. W. White, "Motivation Reconsidered: The Concept of Competence," *Psychological Review, 66,* pp. 297-333, 1959.
6. M. Csikszentmihalyi, *Creativity: Flow and the Psychology of Discovery and Invention,* Harper Collins, New York, 1997.
7. B. J. Barron, D. L. Schwartz, N. J. Vye, A. Moore, A. Petrosino, L. Zech, J. D. Bransford, and Cognition and Technology Group at Vanderbilt University, "Doing With Understanding: Lessons from Research on Problem and Project-Based Learning," *Journal of Learning Sciences, 7*(3-4), pp. 271-311, 1998.
8. J. Lave, *Cognition in Practice: Mind, Mathematics, and Culture in Everyday Life,* Cambridge University Press, Cambridge, MA, 1988.
9. T. N. Carraher, D. W. Carraher, and A. D. Schliemann, "Mathematics in the Street and in School," *British Journal of Developmental Psychology 3,* pp. 21-29, 1985.
10. J. P. Mestre, "Cognitive Aspects of Learning and Teaching Science," in S. J. Fitzsimmons and L. C. Kerpelman (Eds.), *Teacher Enhancement for Elementary and Secondary Science and Mathematics: Status, Issues, and Problems,* National Science Foundation, Arlington, VA, 1994.
11. L. Resnick and D. Resnick, "Assessing the Thinking Curriculum: New Tools for Educational Reform," pp. 37-75, in B. Gifford and M. O'Connor (Eds.), *Changing Assessments: Alternative Views of Aptitude, Achievement and Instruction,* Kluwer Academic Publishers, Boston, MA, 1992.

Suffer the little children . . . and forbid them not.

Mark 10:14

The Student

Children as Students

Just as there is more than one way to display intelligence, there is more than one way to learn, and children, especially infants, learn differently than adults. Infants and young children have a positive bias to learning physical concepts, causality, numbers, and language rapidly.[1] When children get to the classroom, what do they know already? Do they already know how to learn?

Here are some facts about children and learning:

- Because infants will look at things they find interesting, researchers studied their ability to comprehend patterns of events. After establishing a pattern of flashing a picture two times on the left side of a screen and three times on the right, an infant's gaze pattern is observed. When an infant continues to watch the left side after the first flash, but shifts its gaze to the right after the second flash, it can be assumed that the infant is anticipating the third flash to appear on the right. Therefore, a distinction has been made between one, two, and three events. Using this procedure, infants as young as five months can count up to three.[2]
- Children lack knowledge and experience, but not reasoning. In a study of three- and four-year-olds, the children correctly responded when asked whether an echidna and a statue could move themselves up and down a hill. Though the children had never seen either object before, the children claimed that only the living object (the echidna) could move itself up and down a hill.[3]
- Children are problem solvers, as well as problem generators. When five nesting plastic cups are placed on a table in front of a group of children of 18-36 months, they immediately try to fit the cups together. Although they had seen the cups nested together, there was no real need for them to nest them. They could have stacked the cups or lined them up. Instead, they immediately attempted to nest the cups. The children persisted not because they had to, but because success and understanding are motivating in their own right.[4]
- Adults, particularly parents, can help children make connections between new situations and familiar ones. Recently, the positive effects of reading stories and picture books to infants and young children have been scientifically validated.[5] Additionally, studies of drug-abusing mothers and their infants show how the absence of these critical learning interactions between mother and child depresses three- and six-month-olds' learning.[6]

Children's learning is guided by their parents, grandparents, other relatives and adults, other children, teachers, coaches, caregivers, and others. Their learning influences are not limited to people, as television, books, videos, games, and other devices play roles as well. All of these factors contribute to the development of children as learners, eventually enabling them to learn on their own. It is important that older children, especially students, as well as infants and toddlers, understand what it means to learn and be encouraged to plan, monitor, revise, and reflect upon their learning. Equally important, those who teach children must realize and build on the learning children already have. No child comes to school a *tabula rasa*.

Endnotes

1. J. D. Bransford, A. L. Brown, and R. R. Cocking, *How People Learn: Brain, Mind, Experience, and School*, National Academy Press, Washington DC, 1999.
2. R. L. Canfield and E. G. Smith, "Number-based Expectations and Sequential Enumeration by 5-Month Old Infants," *Developmental Psychology, 32*(2), pp. 269-279, 1996.
3. C. M. Massey and R. Gelman, "Preschooler's Ability to Decide Whether a Photographed Unfamiliar Object Can Move Itself," *Developmental Psychology, 24*(3), pp. 307-17, 1988.
4. J. S. DeLoache, S. Sugarman, and A. L. Brown, "The Development of Error Correction Strategies in Young Children's Manipulative Play," *Child Development, 56*, pp. 928-929, 1985.
5. C. E. Snow, M. S. Burns, and P. Griffin (Eds.), *Preventing Reading Difficulties in Young Children*, National Academy Press, Washington, DC, 1998.
6. L. C. Mayes, R. Feldman, R. N. Granger, M. H. Bornstein, and R. Schottenfeld, "The Effects of Polydrug Use With and Without Cocaine on the Mother-Infant Interaction at 3 and 6 Months," *Infant Behavior and Development, 20*(4), pp. 489-502, 1998.

"If we want to improve America's schools, we will have to apply in the classroom what we know about humans as intelligent, learning, thinking creatures."

John T. Bruer,
Schools for Thought

The Student

Mind and Brain

The physiological findings of brain research, although fascinating, are of use to educators only in their relationship to learning. Bodies of research by neuroscientists and developmental and cognitive psychologists stress the importance of experience in building the structure of the mind by modifying the structures of the brain. Practice builds learning, and there is a relationship between the amount of experience in a complex environment and the amount of structural change in the brain.

Learning Changes the Physical Structure of the Brain

Animals raised in complex environments have a greater number of capillaries per nerve cell and a greater supply of blood to the brain than caged animals, regardless of whether the caged animals live alone or with companions.[1] Experience increases the overall quality of brain functions.

Structural Changes Alter the Functional Organization of the Brain

Learning organizes and reorganizes the brain. Consider the following:

- When young animals are taught a maze, structural changes occur in the visual areas of the cerebral cortex.[2] When they learn the maze with one eye covered by an opaque contact lens, only the brain regions connected to the open eye are altered.[3]
- New patterns of organization in the brain, imposed by learning, are confirmed by electrophysiological recordings of nerve cell activity.[4] These developmental changes in the brain, first observed in rats, have been consistent in mice, cats, birds, and monkeys, and they almost certainly occur in humans.
- The number of learning-imposed connections is less important than the patterns that emerge over time in the organization of those connections.[5]

Different Parts of the Brain Are Ready to Learn at Different Times

Experience helps organize the brain and development is often timed to take advantage of different experiences. Consider the following:

- Very young children can discriminate the smallest units of speech much more acutely than adults, but they lose this ability when certain boundaries are not supported by experience with spoken language. For example, native Japanese speakers typically do not discriminate the "r" from the "l" sounds that are evident to English speakers. The ability to do so is lost in early childhood because it is not present in the speech they hear.[6]

- Reading in Italian activates different regions of the brain than reading in English. For example, English letter combinations often have different sounds in different contexts (e.g., chief, chef, chemistry). Italian letter combinations are much more consistent and demand a less interpretive process.[7]

It is clear that the brain is changed by the experiences it encounters. Intellectual development depends on and benefits from experience. However, as John Bruer cautions, research on the chemical and electrical functioning of the brain may provide little to assist educators.[8] Neuroscience has discovered a great deal about neurons and synapses, but not nearly enough to guide educational practice. Nonetheless, a bridge to practice is being built, one rivet at a time, by cognitive psychologists. Yet, it is not clear in any great detail which educational practices should be changed, eliminated, or added to the teacher's repertoire.

Adapted from J. D. Bransford, A. L. Brown, R. R. Cocking, *How People Learn: Brain, Mind, Experience, and School,* National Academy Press, Washington, DC, 1999.

Endnotes

1. J. E. Black, A. M. Sirevaag, and W. T. Greenough, "Complex Experience Promotes Capillary Formation in Young Rat Visual Cortex," *Neuroscience Letters, 83,* 1987.
2. W. T. Greenough, J. M. Juraska, and F. R. Volkmar, "Maze Training Effects on Dendritic Branching in Occipital Cortex of Adult Rats," *Behavioral and Neural Biology, 26,* 1979.
3. F. L. Chang and W. T. Greenough, "Lateralized Effects of Monocular Training on Dendritic Branching in Adult Split-Brain Rats," *Brain Research, 232,* 1982.
4. C. Beaulieu and M. Cynader, "Effect of the Richness of the Environment on Neurons in Cat Visual Cortex, I. Receptive Field Properties," *Developmental Brain Research, 53,* 1990.
5. P. Huttenlocher and C. de Courteu, "The Development of Synapses in Striate Cortex of Man," *Human Neurobiology, 6*(1), 1987.
6. P. K. Kuhl, "Innate Predispositions and the Effects of Experience in Speech Perception: The Native Language Magnet Theory," in B. deBoysson-Bardies, S. deSchonen, P. Juscyzyk, P. McNeilage, and J. Morton (Eds.), *Developmental Neurocognition: Speech and Face Processing in the First Year of Life,* Kluwer Academic Publishers, Dordrecht, NL, 1993.
7. E. Paulesce, E. McCrary, et al, "A Cultural Effect on Brain Function," *Nature Neuroscience, 3*(1), January 2000.
8. J. Bruer, "Education and the Brain: A Bridge Too Far," *Educational Researcher, 26*(8), November 1997.

The Teacher

"Don't you understand? I am a teacher. Every day, through my students, I touch the future."

Christa McAuliffe, when asked why she wanted to take part in NASA's Teacher in Space Project in 1985.

The Teaching Profession

Perhaps no profession has the potential to affect the future as dramatically as do teachers. Teachers of mathematics and science introduce students to concepts, methods, and ideas that will shape their lives in innumerable ways. But who are these teachers? What do they give and what do they get back? Why do they continue to teach?

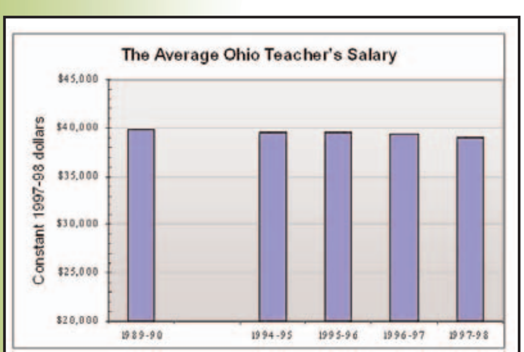
The Teacher's Place in Society

Trust

- Eighty percent of the public consistently gives local public school teachers a grade of A or B.[1]
- Asked about the credibility of public figures speaking out on public issues, U.S. adults rate only Supreme Court justices higher than teachers.[2]

Competence

- Teachers score as well as or better than lawyers, physicians, engineers, marketing and public relations professionals, educational administrators, social workers, and counselors in their ability to understand and use information.[3]
- The average Ohio elementary or secondary school teacher has about 15 years of teaching experience.
- Nearly all (97%) of Ohio teachers hold at least a Bachelor's degree. Half (49%) hold a Master's degree.[4] By comparison, in 1996 less than a quarter (22%) of Ohio's population, age 25 years and over, had completed at least four years of college.[5]
- In college, students who subsequently become high school teachers maintain academic records that are the equivalent of other students'.[6] However, students who become elementary school teachers typically enroll in less challenging courses, take more remedial courses, and score less well on academic aptitude tests.[7]



The Teacher's Reward

Compensation

- The average salary of Ohio public school teachers in 1998-99 was $40,736.[8]
- In 1997-98, the average Ohio teacher's annual salary was $408 below the U.S. average. In constant dollars, Ohio teachers' salaries have been in decline.[9] See figure.

- The typical salary for a beginning teacher in Ohio is about $3,000 per year lower than the U.S. average.[10]
- The following occupations earn more than teachers: physicians; lawyers; electrical engineers; marketing, advertising, and public relations professionals; financial managers; computer systems analysts; education administrators; accountants and auditors; property and real estate managers; and food service and lodging managers.[11]

Stability and Security

- In 1993-94, nearly 65 percent of American public school teachers planned to remain teachers as long as they were able or until eligible to retire.[12]

Unconventional Work Schedule

- Most teachers spend no more than six hours per day in class, and teach approximately nine months of the year. Non-classroom activities—such as creating lesson plans; grading papers; locating materials; talking to parents; and meeting with students, other teachers, and administrators—extend the teacher's typical work week to 50-55 hours.[13]

Gaps and Obstacles: The Real World Versus the Teacher's World

Data confirm that the American public holds it teachers in high regard. As a group, teachers are equally as competent, literate, and capable as those in most other professions. However, they are paid less. Moreover, in Ohio, teachers' real pay has been declining for the past decade.

Some evidence suggests that satisfaction with schools and teachers also may be somewhat lower in Ohio than elsewhere. Data from the 55 largest U.S. cities says that 93 percent of households with children enrolled in public elementary schools are satisfied with their schools. However, in Ohio the percentages of satisfied households are as follows: Columbus, 90 percent; Cincinnati, 82 percent; and Cleveland, 81 percent.[14]

The discrepancy between the responsibilities and expectations of teachers and the salary they are paid may deter qualified college students from pursuing a career in the classroom. The student who is driven to succeed, in academia and in the workplace, is lured to fields other than teaching. Those students who choose to pursue certification as a teacher may not be as relentless in their pursuit of excellence.

Differences between the world of schooling and the business world in both schedule and philosophy also may deter quality candidates. The business world values and rewards competence and successful risk taking. Education provides no similar incentives for teachers. The business world functions on a standard 9 to 5 workday, 12 months of the year, with overtime and extended hours the norm. Teachers operate outside the mainstream, on their own unique nine-month schedule.

The teaching profession is not a player on the business world's economically driven stage. This fact creates a fundamental irony of business-world outsiders teaching students to become business-world insiders.

Endnotes

1. Phi Delta Kappa Teachers' Poll, 1997.
2. National Credibility Index™, Research/Strategy/Management, Inc., conducted for the Public Relations Society of America Foundation and The Rockefeller Foundation, 1998.
3. B. Bruschi and R. Coley, *How Teachers Compare: The Prose, Document, and Qualitative Skills of American Teachers,* Educational Testing Service, Princeton, NJ, 1999.
4. Ohio Policy Inventory for the National Commission on Teaching and America's Children, *The Best Teachers for Ohio's Children,* Ohio Department of Education, Columbus, OH, 1997.
5. Bureau of the Census, "Educational Attainment in the United States: March 1996," *Current Population Reports,* U.S. Department of Commerce, Washington, DC, 1998.
6. R. Henke, S. Geis, and J. Giambattista, *Out of the Lecture Hall and into the Classroom: 1992-93 College Graduates and Elementary/Secondary School Teaching,* National Center for Education Statistics, U.S. Department of Education, Washington, DC, 1996.
7. Educational Testing Service, *The Academic Quality of Prospective Teachers: The Impact of Admissions and Licensure Testing,* Princeton, NJ, 1999.
8. State Board of Education of Ohio, *Annual Report 1998-99: Ohio's Schools: Pride in the Past, Confidence in the Future,* Ohio Department of Education, Columbus, OH, 1999.
9. National Center for Education Statistics, *Digest of Educational Statistics 1998,* U.S. Department of Education, Washington, DC, 1999.
10. Ibid.
11. Bruschi and Coley.
12. National Center for Education Statistics, *Schools and Staffing Survey, 1993-94,* U.S. Department of Education, Washington, DC, 1994.
13. National Education Association, *Status of the American Public School Teacher: 1990-91, Washington, DC, 1992.*
14. A. Carnevale and D. Desrochers, *School Satisfaction: A Statistical Profile of Cities and Suburbs,* Educational Testing Service, Princeton, NJ, 1999.

"Teaching is only the art of awakening the natural curiosity of young minds for the purpose of satisfying it afterwards."

Anatole France, *The Crime of Sylvestre Bonnard*

The Teacher

Teacher Quality

Stories written by and about exemplary teachers are well known.[1] More difficult to find is objective data on how much difference the average teacher can make. What makes for successful teaching? It is a difficult question, with complex and elusive answers—the pursuit of which is necessary and critical.

Do Teachers Make a Difference?

In 1978, three Canadian researchers published a powerful example of the long-term effects of quality teaching. They gathered historical data on first-grade students at an urban elementary school, documenting their academic growth as they progressed through successive grades and studying their successes in life as adults.

They discovered that one group of students not only performed better in each successive grade, but also achieved greater success as adults. The only factor linking those students was that they shared the same first-grade teacher. Judged by their occupation, type of residence, and other socioeconomic factors, students of Miss Apple Daisy[2] were more successful than students of other first-grade teachers at the same school.[3]

As adults, the former students of Miss Apple Daisy easily recalled being in her class, while less than half of the other students correctly identified their first-grade teachers. A few even misidentified Miss Apple Daisy as their teacher!

If one teacher can influence the lives of students so dramatically, imagine the results when a student is fortunate enough to have effective teachers over consecutive years. Recent work is beginning to confirm that good teaching compounds rapidly.[4]

What Makes a Good Teacher?

We know, not surprisingly, that what happens during classroom instruction can have remarkably strong effects on student learning.[5] Recent research findings have uncovered or confirmed teaching methods that make a difference.[6] Nevertheless, what makes a good teacher remains uncertain. Consider the following:

- A major national review[7] of teacher quality and its link to student performance found that training and experience matter:
    - Fourth-grade students whose teachers have a college major in mathematics education or education outperform students whose teachers majored in a field other than education. In eighth grade, students of teachers with a major in mathematics outperform students whose teachers majored in education or other subjects.

- Eighth-grade students whose teachers are certificated in mathematics perform better than eighth-grade students whose teachers are not certified in this area.
- Students who are taught mathematics by teachers with more than five years of teaching experience are more likely to perform better than students taught by teachers with five or fewer years of experience.
- The more knowledge eighth-grade teachers reported of National Council of Teachers of Mathematics (NCTM) standards, the higher their students' mathematics performance tended to be on the National Assessment of Educational Progress (NAEP).

- Effective teachers work differently. They give explanations from multiple perspectives, respond promptly and accurately to student questions, plan lessons systematically and intelligently, qualify assertions appropriately, and choose carefully what they teach and what they do not teach.[8]
- Students whose teachers have good reading skills perform better than students of teachers with lower reading skills.[9]
- Good teachers know *how* to teach. They readily and clearly describe what is important in classroom events, including events others miss. They have a strong clinical sense of what is happening elsewhere in their classrooms, even as they focus on an individual student's learning.[10]

Ohio's Teachers

Ohio's math and science teachers bring a wide variety of qualifications and resources to the classroom:

- Their undergraduate and graduate work gives them exposure to college courses in many diverse subjects.
- The typical, certificated Ohio teacher has 14.9 years of experience.[11]
- Of Ohio's teachers, 48.8 percent hold a Master's degree or higher.[12]
- Ohio's teachers have pursued national board certification actively, resulting in almost 600 nationally certified teachers, more than almost all other U.S. states.[13]

On the other hand, some of the Ohio data raise questions:

- Most states today require teachers to pass examinations on subject-matter knowledge and teaching knowledge. Ohio does not require such testing, although some individual districts do so.[14]
- Ohio is one of only 11 states that do not require a written test of basic skills for beginning teachers.[15]
- Sixty-one percent of Ohio's secondary teachers hold a degree in the subject they teach, slightly below the national average.[16]
- Few of Ohio's math teachers say that the NCTM standards help them choose what and how they teach.[17] On the other hand, these standards, as well as the science standards from the American Association for the Advancement of Science (AAAS), heavily influence Ohio's model curricula and district curriculum guides, which teachers do depend on.

- Ohio's most skilled teachers list professional development as a critical and necessary means to enhance teaching skills.[18] However, research shows that the number of hours of professional development teachers receive is not related to students' performance in mathematics.[19] The problem may be the content of the professional development opportunities currently available to teachers.[20]

Routes and Destinations

Clearly, college education, certification, experience, skill, intelligence, and professional development are all important attributes of good teachers. However, some of today's eighth-grade math students in Ohio are being taught mathematics by teachers who did not major in math in college, may not be certified to teach math, have little or no knowledge of NCTM standards, and may not have a great deal of teaching experience.

Why was Miss Apple Daisy able to make such a difference? The comments of her students, decades after being in her class, are pertinent.[21] She left a "profound impression of the importance of schooling," said one. Another claimed, "She gave extra of herself to students who were slow learners. We all loved her so much, that sometimes we wished we were slow learners, too." A former colleague cited "the sheer force of her personality and her obvious affection for the children." If a student needed a bus ticket, she paid for it. When children forgot their lunches, she gave them her own. "I have a five-year-old son," said another former student, "I only wish I could find an Apple Daisy for him."

If teachers like Miss Apple Daisy are noteworthy because they are the exceptions to the rule, we should not look to create more exceptions, but to find ways to change the rule.

Endnotes

1. The work of Jaime Escalante in Los Angeles was the subject of the 1987 feature film *Stand and Deliver.* Autobiographical descriptions of teachers' work includes S. Ashton-Warner, *Teacher,* Simon & Schuster, New York, NY, 1963; A. S. Neill, *Summerhill,* Hart, New York, NY, 1960; and V. Gussin Paley, *Mollie Is Three: Growing Up in School,* University of Chicago Press, Chicago, IL, 1986. Descriptive reports of teaching also can be found in T. Kidder, *Among Schoolchildren,* Houghton-Mifflin, Boston, MA, 1989; G. McPherson, *Small Town Teacher,* Harvard University Press, Cambridge, MA, 1972; B. Kaufman, *Up the Down Staircase,* Avon, New York, NY, 1964; C. Rathbone, *On the Outside Looking In: A Year in an Inner-City High School,* Atlantic Monthly Press, New York, NY, 1998; and L. Delpit, *Other People's Children: Cultural Conflict in the Classroom,* New Press, New York, NY, 1995. Some descriptions of teaching in Ohio are drawn in the unpublished document *Pathways to System Reform: Case Studies of Ohio Schools,* prepared with funding from a grant from the National Science Foundation to J. Kahle, then of Miami University.
2. Her name was Iole Appugliese (pronounced Yolly Appulyazy). Unable to say this, her first-grade students called her Miss Apple Daisy.
3. E. Pedersen, T. Faucher, and W. Eaton, "A New Perspective on the Effects of First-Grade Teachers on Children's Subsequent Adult Status," *Harvard Educational Review, 48*(1), February 1978, pp. 1-31.
4. The work of William Sanders in Tennessee has most clearly shown the exceptional academic gains children can make when they are taught in successive years by their schools' best teachers: W. Sanders and J. Rivers, "Cumulative and Residual Effects of Teachers on Future Student Academic Achievement," unpublished paper, University of Tennessee (Knoxville), Value-Added Research and Assessment Center, 1996. Similar results have been observed in Dallas: see H. Jordan, R. Mendro, and D. Weerasinge, "Teacher Effects on Longitudinal Student Achievement," paper presented at the Center for Research on Educational Accountability and Teacher Education, Indianapolis, 1997.

Endnotes

5. M. Wang, G. Haertel, and H. Walberg, "Toward a Knowledge Base for School Learning," *Review of Educational Research, 63*(3), Fall 1993, pp. 249-294. Wang and colleagues insist strongly that their research is "inconsistent with current conventional wisdom which argues for policy-driven solutions, like school restructuring, school-site management, and tougher teacher credential requirements and evaluation, to improve student learning." 6. J. Bransford, A. Brown, and R. Cocking (Eds.), *How People Learn: Brain, Mind, Experience, and School,* National Academy Press, Washington, DC, 1999.
7. E. Hawkins and J. Dossey, *School Policies and Practices Affecting Instruction in Mathematics: Findings from the National Assessment of Educational Progress,* National Center for Education Statistics, U.S. Department of Education, Washington, DC, 1998.
8. L. Shulman, "Knowledge and Teaching: Foundations of the New Reform," *Harvard Educational Review, 57*(1), 1987, pp. 1-22.
9. R. Ferguson and H. Ladd, "How and Why Money Matters: An Analysis of Alabama Schools," pp. 265-298, in *Holding Schools Accountable: Performance-Based Reform in Education,* Brookings Institution, Washington, DC, 1996.
10. D. Berliner, "Expertise: The Wonder of Exemplary Performances," pp. 161-186, in J. Mangierie and C. Block (Eds.), *Creating Powerful Thinking in Teachers and Students,* Holt, Rinehart, and Winston, Fort Worth, TX, 1994.
11. State Board of Education of Ohio, *Annual Report 1998-99: Ohio's Schools: Pride in the Past, Confidence in the Future,* Ohio Department of Education, Columbus, OH, 1999.
12. Ibid.
13. See the Web site of the National Board for Professional Teaching Standards (www.nbpts.org/nbpts/).
14. National Center for Education Statistics, *Digest of Educational Statistics 1998,* U.S. Department of Education, Washington, DC, 1999.
15. *Education Week,* "Quality Counts 2000," 19(18), January 2000.
16. National Education Goals Panel, *The National Goals Report: Building a Nation of Learners, 1999,* Washington, DC, 1999.
17. NCREL analysis of OMSC-sponsored teacher survey in Ohio, fall 1999.
18. NCREL-sponsored symposium for exemplary Ohio teachers, Columbus, November 11-12, 1999.
19. Hawkins and Dossey
20. J. Stigler and J. Hiebert, *The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom,* The Free Press, New York, NY, 1999.
21. R. Collins, "Miss Apple Daisy," *Reader's Digest* (Canadian edition), September 1976, pp. 142-147.

"Our schools can be no better than the people who staff them."

Carnegie Forum on Education and the Economy

The Teacher

Teacher Development

To prepare students to compete in today's global economy, schools must teach much more than reading, writing, and arithmetic. They must provide the kind and quality of education once reserved for an elite few.[1]

To meet this challenge, teachers must acquire a greater in-depth knowledge of the content of their field and the teaching methods appropriate to that field.[2] Are the current methods of training teachers adequate? If not, how can they be improved?

Issues

- Teachers are being asked to change how they interact with students. The professional consensus about what constitutes exemplary practice has shifted from a model of "teaching as telling" to "teaching as coaching," with students actively involved in constructing knowledge. Most teachers have not been trained for this type of teaching.
- In 1994, 35 percent of U.S. public schools had access to the Internet; by 1999, that number had risen to 78 percent. In 1994, 3 percent of classrooms had Internet access; by 1999, 63 percent were connected.[3]
- Teachers are being asked to use new and often unfamiliar technologies, including computers with access to the Internet. Yet, many teachers received their professional education before these technologies were available for the classroom.
- Many teachers now are expected to use technology not only as a classroom tool but also for activities such as record keeping, communication with parents, distance learning, professional development, and curriculum development.
- Teachers increasingly are being asked to take on expanded roles and responsibilities outside the classroom, especially in schools where site-based management is being implemented.
- Teachers are managing classrooms that are more diverse culturally and linguistically. And these groups—whether students, parents, or community members—expect their special needs to be served.[4]

Induction Programs for New Teachers

The National Commission on Teaching and America's Future (NCTAF) notes that new teachers often are assigned to classes and left to "sink or swim" with little or no support from more experienced teachers. NCTAF argues that this lack of support for new teachers contributes to high turnover and less effective teaching.[5]

A growing number of schools and districts are implementing formal induction programs to help beginning teachers adjust to their new responsibilities and work environment. Through these programs, experienced teachers help new teachers by providing guidance on pedagogical challenges and chores, ethical dilemmas, student assessment, and classroom management, and by familiarizing new teachers with school programs, policies, and resources.[6]

Professional Development

Professional development once was thought of as a particular kind of activity such as a workshop or course. More recent conceptions include a wider range of activities that emphasize ongoing rather than one-time events and that focus on teachers' own practice rather than on someone else's pedagogical formula. Thus, activities such as joint work (where teachers share responsibilities that require teacher cooperation and interdependence), teacher networks, collaboration between schools and colleges, professional development schools, and participation in the assessment process leading to National Board certification now are viewed as professional development activities.

Critics of half-day workshops and other traditional types of professional development claim that they fail in both content and duration to address new concepts of teaching and learning and, thus, do not modify teachers' practices in any meaningful way. Effective programs, on the other hand, share many characteristics.

Effective professional development programs:[7]

- Address content areas central to teachers' needs.
- Are of sufficient duration to allow time for teachers to absorb new ideas and test them in their classrooms, get feedback from others about how they are managing, and then practice some more.
- Are problem-oriented and focus on inquiry and reflection—in and about classroom work and subject matter competence.
- Are collaborative.
- Provide sources of new ideas.
- Are coherent, intensive, and ongoing.
- Connect directly to broad goals for student learning and school improvement.

States historically have not played a lead role in shaping professional development except for their influence on the initial preparation of teachers through their regulation of teacher education programs. Now, however, many states are taking a more active role and trying to influence the focus, scope, and quality of professional development as well as its quantity.[8] Corcoran has identified the steps some states are taking to improve teacher professional development.[9] These include:

- Finding out how much is being spent for professional development and how it is being spent
- Conducting policy reviews to determine the impact of state policies on local decision making
- Developing guidelines, standards, and incentives for districts and schools
- Reexamining how time for professional development is being used

In addition, the National Board for Professional Teaching Standards (NBPTS) is working with teachers and teacher organizations to establish standards for advanced practice and a rigorous assessment and certification process. Ohio has been at the forefront of states encouraging national teacher certification.

Endnotes

1. Carnegie Forum on Education and the Economy, *A Nation Prepared: Teachers for the 21st Century,* Rochester, NY, Author, 1986. However, Paul Barton points out that occupations with both the highest and lowest requirements are growing at above-average rates (P. Barton, *What Jobs Require: Literacy, Education, and Training, 1940-2000,* Princeton, NJ, Educational Testing Service, 2000.).
2. National Commission on Teaching and America's Future (NCTAF), *What Matters Most: Teaching for America's Future,* New York, NY, Author, 1996.
3. National Center for Education Statistics, *Stats in Brief: Internet Access in U.S. Public Schools and Classrooms, 1994-1999,* Washington, DC, Author, 2000.
4. In the fall of 1986, 70.4 percent of U.S. students in grades K-12 were white, 16.1 percent were black, and 9.9 percent were Hispanic. Eleven years later in the fall of 1997, white students comprised 63.5 percent of the K-12 student population, blacks 17.0 percent, and Hispanics 14.4 percent. Despite much furor, the racial distribution changed little. Ohio's change was hardly noticeable: 83.1 percent white in 1986, 81.7 percent in 1997; 15.0 percent black in 1986, 15.6 percent in 1997; 1.0 percent Hispanic in 1986, 1.5 percent in 1997. (National Center for Education Statistics, *Digest of Education Statistics, 1999,* Washington, DC, Author, 1999.)
5. NCTAF, 1996.
6. Ibid.
7. M. Smylie, "From Bureaucratic Control to Building Human Capital: The Importance of Teacher Learning in Education Reform," *Educational Researcher, 25*(7), 1996, p. 10. See also J. Stigler and S. Hiebert, *The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom,* New York, NY, Free Press, 1999.
8. E. St. John, J. Ward, and S. Laine, *State Policy on Professional Development: Rethinking the Linkages to Student Outcomes,* Oak Brook, IL, North Central Regional Educational Laboratory, 1999.
9. T. Corcoran, "Helping Teachers Teach Well: Transforming Professional Development," *CPRE Policy Briefs,* June 1995.

...And then the whining school-boy, With his satchel, and shining morning face, Creeping like a snail, unwillingly to school.

William Shakespeare,
As You Like It

The Classroom

Means and Consequences

Although it's been nearly 400 years since Shakespeare wrote these lines, the attitudes of today's children toward school haven't changed much.

In fact, neither has school itself. If you could walk into your great grandmother's fifth-grade classroom, you would find neat rows of wooden chairs behind small desks, a larger desk at the front of the room, a blackboard, a stack of well-worn books on a shelf against the wall, and a teacher talking or monitoring student work—much the same scene as you would see in many of today's classrooms. As society evolves from generation to generation, the core of classroom activity has remained remarkably unchanged.[1]

There have been many attempts to examine and measure the effect of what happens in classrooms, but few concrete answers. Do schools make a difference? What about textbooks, technology, and other tools of education? If we want to improve students' classroom experiences, where do we begin?

The Consequences: What Do Students Learn in the Classroom?

In 1968, Robert Dreeben suggested that what happens to children in school shapes what they learn, above and beyond the explicit lessons taught. "If schooling forms the linkage between the family life of children and the public life of adults," Dreeben wrote, "it must provide experiences conducive to learning the principles of conduct and patterns of behavior appropriate to adulthood."[2] The ways in which schools choose to organize, present, and execute teaching and the environment in which teaching is done strongly shape and limit what students learn.

Another obvious purpose of schools is to increase knowledge and skill. People with more education have more knowledge than those without.[3] Moreover, people with more schooling in youth tend to receive more training as adults.[4] The consequences of schooling differ with each student, each teacher, and each school, but adults carry the knowledge they learned in school for decades. Not only do they remember facts and information, throughout their lives they use learned skills to acquire new knowledge and information.[5]

The Means: How Are the Consequences Achieved?

To improve the results of today's schools, we need to examine what they are doing to produce these results:

- How are students being taught? (see the Learning Tasks fact sheet)
- What is being asked of them in class? (see the Classwork fact sheet)
- What is being asked of them outside of class? (see the Homework fact sheet)

- What tools are being used and are they being used effectively? (see the Materials and Technology fact sheet)
- How are lessons planned and developed? (see the Lesson Plans fact sheet)

The Future: Where Do We Go From Here?

The one-room schoolhouse has grown into a self-contained campus with its own library, gymnasium, playground, computer lab, and media center. Textbooks have been rewritten over and over again. The abacus gave way to the calculator, which in turn is giving way to the personal computer. The settings are bigger and better, the tools have more bells and whistles, but life in Ohio's classrooms appears to remain much the same.

To affect change in education, our focus, like the student's, needs to be directed to the front of the classroom. The tools and technology change constantly, but books, calculators, and computers alone do little to alter our students' education. Subject matter also changes and evolves without affecting the rate of student learning. The factor that historically has not changed much is *how* we teach.

If we want attitudes toward school to move beyond that of Shakespeare's whining schoolboy, the classroom must become a place to which students will walk, if not run. New books won't make that happen. Nor will computers, new buildings, or athletic facilities. New ways of teaching that engage student *and* teacher just might.

The power to find out rests in the hands of teachers.

Endnotes

1. L. Cuban, *How Teachers Taught: Constancy and Change in American Classrooms, 1880-1990,* Teachers College Press, New York, NY, 1993. Although classrooms have not changed much, schools have. They are now much larger, more clearly age-graded, better equipped, and provide many more nonacademic services.
2. R. Dreeben, *On What Is Learned in School,* Addison-Wesley, Reading, MA, 1968.
3. H. Hyman, C. Wright, and J. Reed, *The Enduring Effects of Education,* University of Chicago Press, Chicago, IL, 1975. Also see M. Rutter, B. Maughan, P. Mortimore, and J. Ousten, *Fifteen Thousand Hours: Secondary Schools and their Effects on Children,* Harvard University Press, Cambridge, MA, 1979.
4. Education combines with other influences to make adult learning least common among those who most need it. See Organization for Economic Cooperation and Development, *Education at a Glance: OECD Indicators, 1998,* Paris, 1999.
5. Hyman, Wright, and Reed.

Learning Tasks

What kind of work should students do in school? It is a question that lies at the heart of education and debates about education. The Third International Mathematics and Science Study (TIMSS) addressed this question by videotaping classroom activity in the United States, Germany, and Japan. The results revealed great differences between American classroom practice and most especially Japan's, where student achievement in math and science is consistently higher.

Overall, Japanese teachers use methods that, according to current research, are proven to be effective. By contrast, U.S. teachers use more outdated practices and techniques.

- Research confirms that learning is enhanced when students do most of the mathematics work during a lesson rather than watching the teacher do the work for them.[1] In Japan, students are asked to perform 40 percent of their math work in class. U.S. students are asked to do only about 9 percent of the work in class.[2]
- Reviews of research show that two obvious factors influence how much and how well students learn in school:[3]
    1. *Quantity of instruction*—the amount of time students spend actively learning
    2. *Metacognition*—how children monitor their own learning, intentionally planning to become more effective learners and continuously testing, revising, and evaluating learning strategies
- Quality teams, collaborative research teams, and project groups are common ways of organizing to get work done in the world outside school. Small-group learning also has a long history in education. However, while businesses give such groups considerable autonomy, teachers rarely give student groups similar independence. Consider the following:
    - TIMSS revealed that 11 percent of all U.S. fourth-grade math teachers report having students work in small groups without direct teacher assistance most or all of the time. For eighth grade, the figure is 12 percent.
    - In Ohio, 10 percent of third- and fourth-grade math teachers report having students work in small groups without direct teacher assistance most or all of the time.
    - In Ohio, 9 percent of seventh- and eighth-grade math teachers have students work in small groups most or all of the time.
    - In Ohio, 10 percent of math instruction in 12th grade occurs mostly in independent small groups.[4]

- Teachers in lower grades, who spend more time per week with the same group of students than teachers in higher grades, are more likely to use small-group instruction and to conduct classroom discussions about classwork.[5]
- At least once a week, about two-thirds of U.S. teachers ask students to explain how what they have learned in class relates to the world outside class. Teachers in lower grades ask this question more frequently than teachers in higher grades.[6]

Learning tasks chosen by Ohio's teachers are not unlike those in the rest of the nation's classrooms. However, there are alternatives. In suburban Chicago, the First in the World Consortium has achieved much different results. For this group, 23 percent of fourth-grade math classes and 16 percent of eighth-grade math classes work in independent groups most of the time.[7] These students outperformed all countries participating in TIMSS, except Singapore. Science classes followed a similar pattern.

It is clear that using small-group learning, teaching real-world applications, and asking students to do work in class are not new teaching concepts or techniques. They are all basic elements of any teacher's repertoire. Essentially, Japanese teachers and American teachers use many of the same techniques. But they use them differently to deliver different content.

Though teachers may be familiar with the basic principles of pedagogy, they also must be aware of ways to structure classroom tasks that maximize learning in the subject they are teaching. As the research shows, effective math teachers not only know *math*, and know how to teach, they also know how to *teach math.*

Endnotes

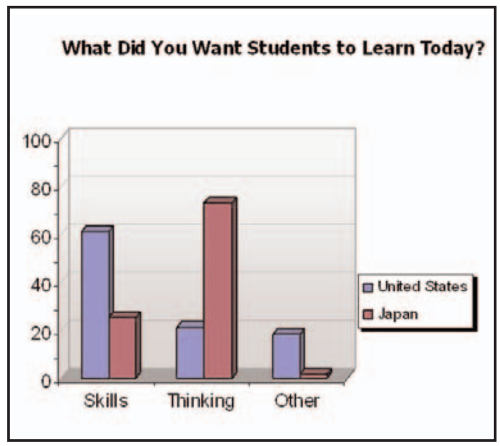
1. W. Doyle, "Work in Mathematics Classes: The Context of Students' Thinking During Instruction," *Educational Psychologist, 23,* 1988, pp. 167-80.
2. J. W. Stigler and J. Hiebert, *The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom,* The Free Press, New York, NY, 1999, p. 68.
3. M. C. Wang, G. D. Haertel, and H. J. Walberg, "What Influences Learning? A Content Analysis of Review Literature," *Journal of Educational Research, 84*(1), Sept/Oct 1990.
4. North Central Regional Educational Laboratory analysis of OMSC-sponsored Teacher Survey, 1999.
5. R. R. Henke, X. Chen, and G. Goldman, *What Happens in Classrooms? Instructional Practices in Elementary and Secondary Schools, 1994-95,* National Center for Education Statistics, U.S. Department of Education, Washington, DC, 1999.
6. Ibid.
7. P. Kimmelman, D. Kroeze, W. Schmidt, A. van der Ploeg, M. McNeely, and A. Tan, *A First Look at What We Can Learn from High-Performing School Districts: An Analysis of TIMSS Data from the First in the World Consortium,* National Institute on Student Achievement, Curriculum, and Assessment, U.S. Department of Education, Washington, DC, 1999.

The Classroom

Classwork

The brief and finite amount of time teachers have with their students makes use of that time crucial. In high school or middle school, students may spend only 45 or 50 minutes per day in a math or science class. How are teachers making use of that time? What is being asked of students in class? What do students do in class?

- What teachers try to accomplish during instruction varies internationally. When asked, "What was the main thing you wanted students to learn from today's lesson?"[1]
  - Sixty-one percent of U.S. eighth-grade math teachers responded "skills," meaning they wanted students to learn how to solve specific kinds of problems or to use standard formulas.
  - Twenty-one percent answered "thinking," meaning their lesson emphasized students' exploration, development, or comprehension of mathematical issues or concepts.



  - Responses from Japanese teachers, whose students score near the top in most international mathematic achievement comparisons, were exactly reversed. Seventy-three percent said "thinking," while 25 percent said "skills."
- Some 72 percent of U.S. fourth-grade math teachers and 59 percent of eighth-grade math teachers report they have their students practice computational skills during most or all lessons.[2]

  In Ohio, the comparable percentages are higher: 82 percent in third and fourth grade and 74 percent in seventh and eighth grade. Even in Ohio's 12th-grade classes, computational practice occurs in most or all classes, according to 58 percent percent of the math teachers.[3]
- About two-thirds of U.S. teachers ask students to complete routine exercises from workbook pages or worksheets every day.[4]
- Most lessons divide into periods of classwork or seatwork. Classwork is the time teachers spend working with all of the students, usually orchestrating discussion or lecturing. Seatwork refers to the time when students work individually or in small groups.

  - In the U.S., the sequence of activities and balance between classwork and seatwork is very much the same from classroom to classroom.[5]
  - In the U.S., as in many other countries, teachers spend more time on classwork than seatwork.[6]
  - Japanese teachers keep periods of classwork shorter and use more frequent periods of seatwork.[7]
- Major reviews of research confirm that the factors that most influence learning are those most closely related to the student. Factors consistently cited are:[8]
  - *Classroom management:* Teachers using strategies that maintain active participation by all students.
  - *Student/teacher interaction:* Students responding positively to questions from other students and from the teacher.
  - *Classroom climate:* Cohesiveness of class members, sharing common interests, values, and goals.
  - *Peer group influence:* Level of peers' academic aspirations and engagement.

In the short time each day that math and science teachers have with their students, use of every minute must be examined and evaluated. Are students simply filling out workbook pages or watching films or videos? Is the teacher spending most of the time lecturing, while (it is hoped) students take notes? Are students actively engaged in the process of learning or is their focus elsewhere?

As teachers share more and more of those minutes with technology, more attention must be paid to classroom activities and the distribution of time to each. Spending time in diligent drilling and practice holds much less value than developing skills and knowledge that can be extended beyond the narrow context in which they are learned.[9] Knowing how to solve a math problem in the classroom may not transfer to solving math-related problems outside the classroom.

Endnotes

1. J. W. Stigler, P. Gonzales, T. Kawanaka, S. Knoll, and A. Serrano, *The TIMSS Videotape Classroom Study: Methods and Findings from an Exploratory Research Project on Eighth-Grade Mathematics Instruction in Germany, Japan, and the United States,* U.S. Department of Education, National Center for Education Statistics, Washington, DC, 1999.
2. M. O. Martin, I. V. S. Mullis, A. E. Beaton, E. J. Gonzalez, T. A. Smith, and D. L. Kelly, *Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study,* Boston College, Center for the Study of Testing, Evaluation, and Educational Policy, Chestnut Hill, MA, 1997; and A. E. Beaton, M. O. Martin, I. V. S. Mullis, E. J. Gonzalez, T. A. Smith, and D. L. Kelly, *Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study,* Boston College, Center for the Study of Testing, Evaluation, and Educational Policy, Chestnut Hill, MA, 1996.
3. NCREL analysis of OMSC-sponsored teacher survey, fall 1999.
4. R. Henke, X. Chen, and D. Goldman, *What Happens in Classrooms? Instructional Practices in Elementary and Secondary Schools, 1994-95,* U.S. Department of Education, National Center for Education Statistics, Washington, DC, 1999.
5. S. Olson, "Candid Camera," *Editorial Projects in Education,* 10, pp. 28-32, 1999.
6. *Attaining Excellence: TIMSS as a Starting Point to Examine Teaching, Moderators' Guide to 8th-Grade Mathematics Lessons: United States, Japan, and Germany,* an Eisenhower National Clearinghouse project, September 1997.
7. Ibid.
8. M. Wang, G. Haertel, H. Walberg, "What Influences Learning? A Content Analysis of Review Literature," *Journal of Educational Research, 84,* 1, Sept/Oct, 1990.
9. J. Bransford, A. Brown, R Cocking, *How People Learn: Brain, Mind, Experience, and School,* Washington, DC, National Academy Press, 1999.

HOMEWORK

How important is homework in learning? Do teachers assign homework as a supplement to what is taught in class or do they assign it to make up for what they don't have time to teach in class? Is too much homework assigned or not enough? Does homework lead to learning or is it just "filler"?

Internationally, homework assignment at Grade 8 ranges from a low in Sweden, where only 3 percent of students receive math homework three or more times a week, to a high in Cyprus, Greece, Ireland, Lithuania, Romania, and Slovenia, where 98 percent of the students take math work home three or more times per week. In Japan, this proportion is 22 percent. In the U.S., 87 percent of eighth graders take home math homework three or more times per week.[1] In science, the variety among nations is similar but the amount of homework is somewhat less.[2]

- In Ohio, math and science homework is assigned to students slightly more often than the U.S. national average, and about even with international averages.[3]
  - Of Ohio's third- and fourth-grade students, 66 percent receive math homework assignments three or more days per week.
  - The figure rises sharply to 92 percent for seventh- and eighth-grade students and 97 percent for high school seniors.
  - In science, homework is less frequently assigned; 90 percent of third and fourth graders receive science homework assignments less often than once or twice per week.
  - Eighty-three percent of seventh- and eighth-grade science students receive homework one to four times per week.
  - Seventy-eight percent of Ohio's seniors in science classes take home science work four times a week or more.
- Typically, in Ohio and the rest of the U. S., homework consists of repetitive practice exercises. A sampling of U.S. teachers was asked which types of tasks they assigned to students as homework on a weekly basis:[4]
  - Sixty-five percent reported they had students complete routine exercises as homework.
  - Forty-three percent said they assigned tasks that required applying concepts in new contexts.
  - Twenty-three percent assigned project or experiments.
  - Thirteen percent gave problems with no clear solutions.
- As a group, U.S. teachers spend more time reviewing homework in class than teachers in other countries. Teachers in most other countries spend little or no time on homework in class.[5]

Feedback is fundamental to learning, but feedback opportunities can be scarce in the classroom.[6] Students receive credit or grades on tests and essays, but these assessments occur at the end of the assignment or project. Homework, too, should be graded daily. Delayed feedback is of little value. Teachers who assign homework do students a significant disservice if the work is not graded and reworked promptly and returned to the student.

If the learning goal is to enhance understanding and applicability of knowledge, it is not enough to give homework assignments and tasks that focus primarily on repetition, drill, and practice.[7] The major function of homework is to provide formative, constructive assessments along the way—input that gives students opportunities to revise and improve the quality of their thinking and understanding.

Endnotes

1. A. Beaton, I. Mullis, M. Martin, et al., *Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study,* Boston College, TIMSS International Study Center, Chestnut Hill, MA, 1996.
2. A. Beaton, M. Martin, and I. Mullis, et al., *Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study,* Boston College, TIMSS International Study Center, Chestnut Hill, MA, 1996.
3. NCREL analysis.
4. R. Henke, X. Chen, and G. Goldman, *What Happens in Classrooms? Instructional Practices in Elementary and Secondary Schools, 1994-95,* National Center for Education Statistics, U.S. Department of Education, Washington, DC, 1999.
5. L. Peak, *Pursuing Excellence: A Study of U.S. Eighth-Grade Mathematics and Science Teaching, Learning, Curriculum, and Achievement in International Context: Initial Findings from the Third International Mathematics and Science Study,* National Center for Education Statistics, U.S. Department of Education, Washington, DC, 1997.
6. J. Bransford, A. Brown, and R. Cocking, *How People Learn: Brain, Mind, Experience, and School,* National Academy Press, Washington, DC, 1999.
7. Ibid.

MATERIALS AND TECHNOLOGY

Life in the 21st century will require personal competence with technology, information processing, communication, and decision making. With the integration of technology into every aspect of the workplace, the integration of technology in teaching and learning is essential. New technologies offer increasingly versatile tools that can supplement and reinforce, not replace, student learning.

What Materials and Technology Are Being Used and Are They Effective?

- Print materials have been and remain mainstays of U.S. elementary and secondary education.[1] Textbooks that present, explain, and summarize dominate the introduction of new material. Workbooks and dittos dominate practice.
- Recent research suggests strongly that students perform better when working more with original materials rather than with the routine summaries typically provided in textbooks, workbooks, or worksheets.[2]
- Better understanding of arithmetic can be developed in students with a curriculum that emphasizes estimation, mental arithmetic, and calculator use, with reduced instruction on paper-and-pencil calculation. Indeed, some evidence suggests that over-emphasis on manual skills hinders children's learning of when and how to use those skills.[3]
- Students using exploratory computer graphics programs may perform as well as or better than students using traditional criteria.[4] For mathematical concepts such as data analysis or functions, appropriate use of the computer and software enhances student interest in and understanding of important ideas.
- Computers and other electronic technologies are readily available in Ohio's classrooms:
    - By early 1999, 88 percent of Ohio public classrooms had access to the Internet, slightly below the national average of 90 percent.[5]
    - CD-ROM technology is available in Ohio at a ratio of one CD-ROM drive to every 6.9 students. This figure ranks eighth among all U.S. states.[6]
- However, computers are rarely used in Ohio's math and science classes:
    - Fifty percent or more of Ohio's math and science teachers reported that they never used computers to do exercises or solve problems in 1998-99.[7]
    - Nevertheless, comparable data for the U.S. suggest that Ohio's teachers are slightly *more* apt to use computers in math and science instruction.[8]

A number of the features of new technologies are consistent with the principles of learning: direct experience, rapid feedback, and original materials. Consider the following:[9]

- The interactivity of new technologies makes it easier to create environments in which students can learn by doing, get feedback, and refine their understanding with less dependence on the teacher.
- Using technology, students can better visualize difficult-to-understand concepts, such as differentiating heat from temperature. Working with real-world software applications in school will only benefit students when they encounter the same applications outside the classroom.
- The Internet, CD-ROMs, and other digital technologies give students and teachers instant access to millions of pages of information, libraries, and other reference sources, real-world data, and the ability to communicate with other people.

With successful local, state, and federal governmental efforts to get computers into schools, it brings up the critical question of use. Is the technology being used? How is it being used? What kinds of additional training do teachers need to take full advantage of the technology's capabilities?[10] How can the technology be used to facilitate teacher learning?

For example, the technology exists to link world-class physics researchers with local classroom physics teachers. The benefits of such a link are virtually unlimited:[11]

- Researchers may gain a greater understanding of why learners fail to grasp core concepts of the field.
- Teachers may gain a better understanding of theories and relationships of concepts they teach.
- Students may gain a better understanding of the relationship of concepts learned in the classroom to their application in the real world.

The potential for the use of technology in the classroom is exciting.[12] However, without properly trained teachers to guide the way for student users, an expensive new computer in a school classroom has as much educational value as a dusty textbook on a shelf.

Endnotes

1. C. F. Kaestle, *Pillars of the Republic: Common Schools and American Society,* National Research Council, Washington, DC, 1996. Attempts to digitize textbooks have so far been unsuccessful, despite pressure from states as large as Texas.
2. National Research Council, *National Science Education Standards,* National Academy Press, Washington, DC, 1996.
3. Mathematics Sciences Education Board (MSEB), *Reshaping School Mathematics: A Philosophy and Framework for Curriculum,* National Academy Press, Washington, DC, 1990.
4. Ibid.
5. *Technology in Education: A Comprehensive Report on the State of Technology in the K-12 Market,* Market Data Retrieval, Shelton, CT, 1999.
6. Ibid.
7. NCREL analysis. The single exception was in 12th-grade science classes, where just over half of the teachers said they used computers in some lessons.
8. I. Mullis, M. Martin, A. Beaton, et al., *Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study,* Boston College, TIMSS International Study Center, Chestnut Hill, MA, 1997; and A. Beaton, I. Mullis, M. Martin et al., *Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study,* Boston College, TIMSS International Study Center, Chestnut Hill, MA, 1996.
9. J. Bransford, A. Brown, and R. Cocking, *How People Learn: Brain, Mind, Experience, and School,* National Academy Press, Washington, DC, 1999.
10. Teachers need to learn how to use and manipulate technology, how to integrate it into classwork productively, and how to locate or build useful technologies. These skills require time and other resources. Please see *Report to the President on the Use of Technology to Strengthen K-12 Education in the United States,* Executive Office of the President of the United States, Washington, DC, March 1997.
11. Bransford, Brown, and Cocking
12. B. Means and K. Olson, *Technology's Role in Education Reform: Findings from a National Study of Innovating Schools,* SRI International, Menlo Park, CA, 1995.

Lesson Plans

With increased pressure being put on school systems to meet standards and higher levels of student achievement, the teacher shoulders the daily burden of deciding how to teach more content more effectively in the same amount of time or less. The blueprint for achieving this daunting challenge is the lesson plan. How are lessons planned and developed?

How Do Teachers Determine *What* to Teach?

Ohio math and science teachers were asked to specify the dominant influences on what they choose to teach:[1]

- At elementary and middle school levels, about 60 percent cited district curriculum guides and the Ohio proficiency test frameworks.
- At the elementary level, the Ohio Department of Instruction's model curricula are influential for another 20 to 30 percent.
- In high schools, school curriculum guides are important, as are national standards, together accounting for another 20 to 30 percent.

Despite this guidance, Ohio teachers, like those in the rest of the U.S., teach many topics each year—about 10 more per year than the international average. Further, there is little agreement on which topics to teach or the amount of emphasis to give them.[2]

- Most Ohio teachers spend less than 5 lessons on any one subject topic in math and science.
- While Ohio's schools' curricula expect teachers to cover somewhat fewer topics in elementary school than is true across the U.S., from eighth grade through high school, some 30 topics are expected to be taught each year in Ohio, markedly more than in U.S. high schools typically.

How Do Teachers Determine *How* to Teach?

- Teacher editions of textbooks dominate the choice of teaching methods in Ohio's math classes. They were named as the primary source by 40 to 55 percent of the teachers.[3]
- Twenty to thirty percent of the math teachers said they used resources other than textbooks and school, district, state, or national curricular guides.
- In science, 30 to 40 percent chose other resources, while 20 to 35 percent said textbooks.

Implementing and integrating learning tasks in the classroom, classwork, homework, materials, and technology begins with the lesson plan. With so many options available to the teacher and a limited time in which to use them, devising an effective, engaging lesson plan is critical.

An efficient and productive lesson plan should be based on two fundamental perspectives on learning:[4]

1. *Learner-centered instruction* begins with and builds on the knowledge and experience students bring to the classroom. This includes cultural practices and beliefs, as well as knowledge of academic content.

2. *Knowledge-centered instruction* provides students not only with knowledge and skills, but with the ability to apply them to solve problems.

Both perspectives should influence and permeate the design of a lesson plan. A lesson plan that emphasizes an excessively broad range of subjects runs the risk of developing knowledge of disconnected sets of facts and skills. Much more preferable is a lesson plan that helps students make connections within a discipline so that they "know their way around in it" without losing sight of where they are.[5]

Endnotes

1. NCREL analysis of OMSC-sponsored Teacher Survey, Fall 1999.
2. Ibid.
3. Ibid.
4. J. Bransford, A. Brown, and R Cocking, *How People Learn: Brain, Mind, Experience, and School,* National Academy Press, Washington, DC, 1999.
5. Ibid.

Mathematics is not just a collection of isolated facts, it is more like a landscape. The user of mathematics walks only the well-trod parts of the mathematical territory. The creator of mathematics explores its unknown mysteries, maps them, and builds roads through them to make them more easily accessible to everybody else.

Ian Stewart, 1995

THE CULTURE OF MATHEMATICS: SLAYING THE DRAGON

"Does any word strike greater fear in the hearts of American ninth-graders—and their parents—than algebra?" asked a 1998 front-page article in the *Wall Street Journal*. "Students dread algebra, approach it as if it were toxic and, not surprisingly, do badly at it."[1]

Clearly, most American students do not share Ian Stewart's eloquent view of mathematics. Most mathematics curricula and teachers do not present the subject as real and usable in today's setting. As a result, fear, anxiety, dislike, ambivalence, and low self-confidence are pervasive in mathematics classrooms. Mathematics is perceived as irrelevant. Students see it as merely a collection of rules to be memorized and manipulated. Such experiences create the myth that math is only for the fortunate few who "get it."

Why do students so disdain the prospect of venturing down Stewart's well-trod path through the jungle? Is the jungle too ominous and intimidating, or does the path simply need better lighting and friendlier guides?

Math in U.S. Schools

- In a study of fifth-grade math students, an overwhelming number of students who said they dislike mathematics also believed they were not good at it and that they performed worse than their classmates.[2]
- The Third International Mathematics and Science Study (TIMSS) found that:[3]
  - Most eighth graders in the United States study topics that students in many other countries encounter a year earlier.
  - U.S. math lessons seem to place greater emphasis on definitions of terms and less emphasis on the underlying rationale.
  - U.S. instructional materials for math attempt to cover more ground at less depth than the materials in the other countries. U.S. lessons also contain significantly more topics than do Japanese lessons.
  - The number of definitions presented in a U.S. mathematics lessons is about twice as many as in Germany or Japan.
  - U.S. lessons contain significantly more switches from topic to topic than do both Japanese and German lessons. German lessons scored at least four times as high as U.S. lessons in both complexity and connectedness. Japanese lessons scored six times as high.
- According to results of the National Assessment of Educational Progress (NAEP), only about 1 in 7 high school seniors is proficient in math.[4]
- Seventy-five percent of Americans stop studying math before they complete their career or job prerequisites. [5]

- Sixty percent of college mathematics students enroll in courses that are taught in high school.[6]
- Almost 40 percent of all 17-year-olds do not have the necessary math skills to hold down a production job in manufacturing. As a result, today's manufacturers now often must seek out college graduates for work that high school graduates should be able to perform.[7]
- Major industry and businesses are spending billions of dollars each year training a workforce that is becoming more reliant on computers and technology, while becoming less knowledgeable about how they work. In 1991, employers spent about $63 billion training their workers. By 2005, it is estimated that employers will have to increase training expenditures by more than $15 billion to match 1991 training levels for professional and technical workers.[8]

The Math Gap

U.S. mathematics education at all levels performs poorly, resulting in a less than mathematically literate nation. Why is "math anxiety" such a common condition in the U.S.? Why can't American teachers and schools interest and motivate students in mathematics as teachers in other countries do?

The following is a comparison of what is being taught about math in our schools, and what mathematics really is:[9]

In Schools	As a Discipline
Mathematics is neat and concise. It is about memorizing correct procedures or algorithms for solving well-defined problems.	Mathematics is messy. It involves a search for sense and order from complex, ill-defined situations.
Speed and correct answers are emphasized.	Persistence and flexibility are essential to mathematical pursuits. Mathematicians often spend years trying to solve a single problem.
Answers are validated by the teacher or answer book.	There is no answer book. Often there are no "best" answers or even a guarantee that an answer will be found.
Calculators may be used only once basic skills are mastered. Computers and other technologies are useful primarily for drill but also for enrichment.	Tools (manipulatives, computers, calculators) are continuously used to examine and represent ideas or extend thinking. Tedious computations are done by machines. Thinking and reasoning are done by people.
Math is done in isolation, working quietly from a textbook or a worksheet.	Math is a collaborative endeavor with mathematicians and others working together, communicating their ideas and building on one another's ideas and experiences.

Routes and Destinations

It is not unreasonable to argue that the responsibility for the prevailing level of math literacy of our students falls squarely on the shoulders of the American education system and ultimately our teachers. The system has put forth tremendous resources toward reform; however, it is not clear that there has been much change in the culture of teaching. Teachers as a group continue to teach mathematics in much the same way they always have taught it.

Successful math teachers are not only those with expertise in mathematics, but also those with expertise in teaching[10] and further expertise in teaching mathematics. Expert teachers with expertise in pedagogy and mathematics know what is easier for students to master in mathematics and what is harder, and they adjust their teaching accordingly.[11]

Successful math teaching:

- Gets students involved with the ideas and concepts behind mathematics.
- Capitalizes on their capacity for making connections.
- Defines and connects their work to critical pieces of accepted arithmetic, algebraic syntax, and historical knowledge.
- Assesses students' knowledge of skills, content, and mathematical process.

To the typical mathematics student, math is a beast to be feared—a dragon from which to run. An equally difficult dilemma, however, faces the math teacher who stands before a classroom of students who don't want to be there. The teacher is most likely armed with knowledge of math, and perhaps even knowledge of teaching, but is he or she adequately prepared to break down the barriers that separate students from the desire not just to learn but to understand?[12]

Endnotes

1. J. Kronholz, "Low X-pectations: Here's Y the Teaching of Algebra in the U.S. Has Been Such a Flop," *Wall Street Journal,* June 6, 1998.
2. V. Stuart, "Math Curse or Math Anxiety?" *Teaching Children Mathematics, 6*(5), January 2000.
3. J. W. Stigler and J. Hiebert, *The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom,* The Free Press, New York, 1999.
4. I. V. S. Mullis et al, *NAEP 1992 Mathematics Report Card for the Nation and States* [Report No. 23-ST02], National Center for Education Statistics, U.S. Department of Education, Washington DC, 1993.
5. National Research Council, *Everybody Counts: A Report to the Nation on the Future of Mathematics Education,* National Academy Press, Washington DC, 1989.
6. Ibid.
7. R. J. Murnane and F. Levy, *Teaching the New Basic Skills,* The Free Press, New York, 1996.
8. A. P. Carnevale, *Education and Training for America's Future,* The Manufacturing Institute, Washington DC, 1998.
8. R. E. Parker and K. Richardson, *Mathematical Power: Lessons from a Classroom,* Heinemann, Portsmouth, NH, 1993.
10. L. Shulman, "Knowledge and Teaching: Foundations of the New Reform," *Harvard Educational Review, 57,* 1987.
11. J. P. McDonald and P. Naso, *Teacher as Learner: The Impact of Technology,* Educational Technology Center, Graduate School of Education, Harvard University, Cambridge, MA, 1986
12. Some teachers and schools are adequately prepared to do so, such as the math and science classes at Bedford Road Collegiate Institute in Saskatoon, Canada, described in *Scientific American, 281*(4), p. 91, October 1999.

"When someone says science teaches such and such, [they are] using the word incorrectly. Science doesn't teach it; experience teaches it....It is very important that if you are going to teach people to make observations, you should show that something wonderful can come from them..."

Richard Feynman, addressing the National Science Teachers Association, April, 1966

THE CHALLENGE OF SCIENCE: INQUIRY, DISCOVERY, AND FUN

Science is an enormous enterprise. Teaching even a part of it must be a process in thoughtful decisionmaking. Before 1955, the typical science education curriculum used a direct instruction format. It "emphasized knowledge of scientific facts, laws, theories, and applications" and used some laboratory activities to verify concepts previously covered in class. Since then, however, science has been taught with more *discovery-oriented instruction*, emphasizing "the nature, structure, and processes of science."[1]

The discovery-oriented approach integrates laboratory activities into classroom discussion and places greater importance on hands-on, as well as minds-on, activity. While time consuming, students learn how to solve problems in science, gain experience in scientific reasoning, and learn important science content. They experience, firsthand, the delight that new discoveries can bring.

Teachers are faced with the dual challenge of getting students interested in science and keeping them interested, while at the same time meeting achievement standards and expectations. In deciding how to teach science, teachers must ask themselves: What is important for students in my class to know, now? What can and should wait until later? What can they understand? What can be personally investigated by students rather than through media resources? What science materials and processes must students use in their investigations?

Science as inquiry

Scientific inquiry, the quintessential scientific activity, reflects the nature of science or perhaps more accurately, how scientists play the games of science. There are different ways of approaching problems and styles of inquiry in biology, chemistry, earth and space sciences, and physics. In addition, theoretical structures in the different disciplines influence what is observed and how it is observed.

The following is an analytic scheme that determines the inquiry level of activities,[2] each of which has its use in teaching and learning science.

1. *Confirmation.* The student follows a known, specific procedure to verify a concept or principle, or to learn a technique. The student knows what to expect.
2. *Structured inquiry.* The student does not know what results to expect beforehand. Procedures are outlined and the activities and materials provided are structured so that the student can discover relationships and make generalizations from the data collected.

3. *Guided inquiry.* The student is given the problem to investigate but develops the procedures and methods and discovers the concepts or principles.
4. *Open inquiry.* The student develops the problem and the procedure for solving it, interprets the data, and reaches evidence-based conclusions. Open inquiry requires students to use science concepts or principles.

Issues

- Research has shown that learning is enhanced when activities provide students with opportunities to use previously learned concepts and techniques in the process of discovering new ones.[3]
- In elementary science programs, it has been shown that disadvantaged students benefit the most from the use of inquiry in terms of science process, science content, attitude, creativity, and language development. Advantaged students benefit to a somewhat lesser extent except on content knowledge. Students in programs that stress content can be expected to outperform students in activity-based programs that stress process.[4] The reverse is true on process tests. All things being equal, you get what you teach for.
- A major complaint of American teachers regarding inquiry and meaningful tasks in the classroom, is that they do not have as much time to use these techniques as they would like. However, the Third International Math and Science Study (TIMSS) revealed that American eighth graders spend more school hours each year studying science than students in Japan, who routinely perform better in the subject. American eighth graders study science an average of 139 hours each school year. In Japan, students study science for 91 hours each year.[5]
- American science teachers, including Ohio's, typically are expected to teach far more science topics each year than Japanese teachers. American, and Ohio's, students also repeat more content from grade to grade.[6]
- There are several more reasons inquiry is not being given appropriate emphasis in the classroom. They include teacher preparation, classroom management and materials problems, a felt responsibility to prepare students for the next level of schooling and/or testing, confusion over the meaning of inquiry, allegiance to teaching facts, and a belief that inquiry instruction is successful only for above-average ability students.[7] Many teachers also claim inquiry is too slow, the risk is too high, it is too difficult for most students, the approach lacks sufficient structure. They cite reading difficulties as a concern, as well as discomfort with the process and its expense.
- In Ohio, 33 percent of third- and fourth-grade teachers report having students conduct their own science experiments most or all of the time, while for seventh- and eighth-grade science teachers the number jumps to 40 percent.[8] In Japan, 77 percent of students report they conduct science experiments "often" or "almost always."[9]

Scientific inquiry, a dialogue between the natural world and the inquirer, must take into account the differences among students. Students differ in what they know and what they can do. They are less persistent than scientists, but equally as eager to explore their world when their interest is piqued.[10] Scientific inquiries are forms of argument and the emphasis should be on interpretation and the generation of new questions and discovery. Students are learning to participate in the scientific community as apprentices.

The learning environment should be reflective of the culture of science. It should foster involvement in doing science; ideas that are subject to what scientists refer to as "peer review" or critical and thoughtful evaluation by the class; and an emphasis on reasoning based on evidence. Most important, the focus of science education should be to introduce students not to definitions, formulas, and elements for memorization, but to the joy of watching, wondering, trying, and discovering.

Adapted from *Minnesota K-12 Science Framework*, SciMath^{MN}, 1998.

Endnotes

1. SciMath^{MN}, *Minnesota K-12 Science Framework,* St. Paul, MN, 1998.
2. E. Tafoya, D. W. Sumal, and P. Knecht, "Assessing Inquiry Potential: A Tool for Curriculum Decision-Makers," *School Science & Mathematics, 80*(1), pp. 43-48, 1980.
3. G. Lappan and D. Briars, "How Should Mathematics Be Taught?," In I. M. Carl (Ed.), *Prospects for School Mathematics,* NCTM, Reston, VA, 1995.
4. T. Bredderman, "The Effects of Activity-Based Science in Elementary Schools," In M. B. Rowe (Ed.), *Education in the 80s: Science,* National Education Association, Washington, DC, pp. 63-75, 1982.
5. M. Martin, I. Mullis, E. Gonzalez, T. Smith, and D. Kelly, *School Contexts for Learning and Instruction: IEA's Third International Mathematics and Science Study (TIMSS)*, International Association for the Evaluation of Educational Achievement, TIMSS International Study Center, Boston, MA, pp. 72-73, 1999.
6. W. Schmidt, C. Mcknight, and S. Raizen, *A Splintered Vision: An Investigation of U.S. Science & Mathematics Education,* Kluwer Academic Publishers, Boston, 1997; NCREL, NCREL analysis of OMSC-Sponsored Teacher Surveys, NCREL, Oak Brook, IL, Fall, 1999.
7. W. W. Welch, L. E. Klopfer, G. S. Aikenhead, and J. T. Robinson, "The Role of Inquiry in Science Education: Analysis and Recommendations," *Science Education, 65*(1), pp. 33-50, 1981.
8. NCREL Analysis of OMSC-Sponsored Teacher Survey, Fall, 1999.
9. A. Beaton, M. Martin, I. Mullis, E. Gonzalez, T. Smith, and D. Kelly, *Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS)*, International Association for the Evaluation of Educational Achievement, TIMSS International Study Center, Boston, MA, pp. 14-26, 1997.
10. See the sidebar about Bedford Road Collegiate Institute, in W. Gibbs and D. Fox, "The False Crisis in Science Education," *Scientific American, 281*(4), p. 91, 1999.

MATH AND SCIENCE

"Students will not be provoked to inquire, learn, or study what they already know or think they know, or what they consider at the moment to be irrelevant."

Mary Budd Rowe, *Teaching Science as Continuous Inquiry: A Basic*, 1978

MEANINGFUL TASKS

Choosing meaningful learning experiences for students is among the most important instructional decisions a teacher makes. Laboratory work is a distinctive feature of science teaching, while explorations and investigations provide students with tangible mathematical experience. How often are meaningful tasks and concrete materials utilized in today's math and science classrooms and how much value do they have?

Meaningful tasks can be characterized as those that:[1]

- Are challenging, yet within reach of students.
- Pique and take advantage of students' curiosity.
- Are "authentic," building from the students' own involvement.
- Encourage multiple perspectives and interrelated ideas.
- Nest skill development in the context of problem solving and solution making.
- Encourage students to make sense of mathematical and scientific ideas.

Issues

- Learning is enhanced when tasks give students opportunities to use previously learned concepts and techniques in the process of discovering new ones.[2]
- A review of research concerning manipulative use[3] found that:
  - Lessons using manipulative materials are more likely to produce greater mathematical achievement.
  - The inclusion of the concrete stage in a sequence of instruction improves achievement.
  - Studies at every grade level and across a variety of mathematical topics support the importance of the use of manipulative materials.
  - The use of concrete materials is effective with children at all achievement and ability levels.
- Working with concrete materials and in a laboratory also can promote positive attitudes toward math and science. Most students indicate that they prefer lab approaches more than traditional classroom approaches. In the lab, students gain a feeling of being able to achieve curricular objectives independently and an understanding of the experimental aspects within the nature of the subjects.[4]

- Laboratory work provides a wide variety of students with opportunities to be successful in science and math. For low-ability students, concrete representations and laboratory approaches have been proven to be effective since the late 1960s.[5]
- Choosing meaningful tasks involves two important components: the role of context in learning and the role of conceptual conflict in accommodating new knowledge.[6] Context represents the situations in which activities are embedded. These situations become part of what is learned and how the learning is remembered and recalled.[7] Conceptual conflict exists when new information does not seem to fit with what one already knows.
- One complaint of American teachers is that they do not have time to present as many meaningful tasks as they would like. However, the Third International Mathematics and Science Study (TIMSS) revealed that American eighth graders spend more school hours each year studying math and science than students in Japan, who routinely perform better in both subjects. American eighth graders study math an average of 146 hours each school year, and science an average of 139 hours. In Japan, the numbers are 118 hours for math and 91 for science.[8]
- Further research suggests that the advantage of additional time may be negated by the curriculum American teachers are being asked to teach. U.S. teachers, especially mathematics teachers, attempt to teach more topics each year than teachers in most other nations.[9]

Routes and Destinations

- Designing or choosing tasks demands thoughtful and often collaborative planning on the teacher's part. A good investigation is one that not only invites finding one or more solutions but also allows for extensions beyond the immediate problem. Teachers can help facilitate such possibilities by scaffolding questions that allow students to continue reasoning through the problem or by asking challenging questions that motivate students to pursue problem extensions.
- The following list[10] can be used as a guide for evaluating classroom activities and reexamining what students are being asked to do in their textbooks. A rich problem-solving task:
  - Has important, useful mathematics or science embedded in it.
  - May have different solutions or allow for different decisions or positions to be taken or defended.
  - Can be approached by students in multiple ways using different solution strategies.
  - Encourages student engagement and discourse.
  - Requires higher-level thinking and problem solving.
  - Contributes to the conceptual development of students.
  - Promotes the skillful use of mathematical or scientific knowledge or technique.
  - Creates opportunities for teachers to assess what students are learning and where they are having difficulty.

- Engagement is necessary for learning, but it is not enough. Discussion and reflection should accompany active engagement to develop understanding of concepts. While students are engaged in problem-solving tasks, the teacher must listen to students' conversations and ask key questions. This strategy provides the teacher with insights into levels of student understanding and further instructional needs.
- The inherent challenge for the teacher is not only to teach math and science concepts, but also to give meaning and relevance to concepts, applications, and exercises students would otherwise choose not to learn.

Endnotes

1. B. Reys and V. Long, "Implementing the Professional Standards for Teaching Mathematics: Teacher as Architect of Mathematical Tasks," *Teaching Children Mathematics, 1*(5), 1995, p. 297.
2. G. Lappan and D. Briars, "How Should Mathematics Be Taught?" in I. M. Carl (Ed.), *Prospects for School Mathematics,* National Council of Teachers of Mathematics, Reston, VA, 1995.
3. M. N. Suydam, "Using Manipulative Materials to Learn Mathematics," *ERIC/SMEAC Mathematics Education Fact Sheet Number 2,* ERIC Clearinghouse for Science, Mathematics, and Environmental Education, Columbus, OH, 1982.
4. J. H. Vance, "The Effects of a Mathematics Laboratory Program in Grades 7 and 8: An Experimental Study." Doctoral dissertation, University of Alberta, 1969.
5. E. Wasylyk, "Designing Action Mathematics for Low-Ability Students." In *Active Learning in Mathematics, The 1970 Annual of the Mathematics Council of the Alberta Teacher's Association,* Alberta Teacher's Association, Edmonton, Alberta, 1971.
6. M. B. Rowe, *Teaching Science as Continuous Inquiry: A Basic,* McGraw-Hill Book Company, 1978, p. 180.
7. Lappan and Briars.
8. M. Martin, I. Mullis, E. Gonzalez et al., *School Contexts for Learning and Instruction in IEA's Third International Mathematics and Science Study,* Boston College, TIMSS International Study Center, Chestnut Hill, MA, 1999, pp. 72-73.
9. W. H. Schmidt, *A Splintered Vision: An Investigation of U.S. Science and Math Education,* Kluwer Academic Publishing, Boston, MA, 1997.
10. G. Lappan, J. T. Fey, W. M. Fitzgerald, S. N. Friel, and E. D. Phillips, *Getting to Know CMP: An Introduction to the Connected Mathematics Project,* Dale Seymour Publications, Palo Alto, CA, 1996, p. 40.

"It boils down to this—if you can't talk about math, you are unlikely to do it well."

National Council of Supervisors of Mathematics, 1997

INCORPORATING ORAL AND WRITTEN COMMUNICATION

Learning is a social process. It involves checking against personal experience and negotiating with peers and teachers. Ideas must be shared, respected, and available for reflection, discussion, and revision. Writing tasks are a necessary part of math and science learning. They require students to reflect on, analyze, and synthesize the material being studied in a thoughtful and precise way.[1]

Conversations and writing exercises influence students' reasoning ability, construction of mathematical knowledge, problem-solving abilities, self-confidence, and acquisition of social skills.[2] By responding to student communications, either individually or before the whole class, teachers engage in a unique and continuous dialogue that contributes to the process of teaching and learning.[3]

Issues

- Student communication positively influences learning. Time spent in content-oriented interactions with peers and teachers enhances classroom performance and achievement. As students talk about their classroom experiences, they don't merely add new knowledge; what they already know changes.[4]
- Research confirms that increased levels of "on-task" student talk are related to increased achievement. Achievement was significantly higher for groups in which the amount of student talk time was equal to or half as much as teacher talk compared to groups with no student talk.[5]
- Research on problem solving has shown that expository writing is an effective and practical tool for enhancing learning of mathematics concepts and skills.[6]

Gaps and Obstacles

- Facilitating discussions about students' mathematical ideas requires skill and patience. Teachers generally assume responsibility for initiating discussion and maintaining focus, especially with younger children. Thus, it is very important that teachers strengthen their skills in facilitating student discourse. This topic is neglected in many teacher preparation sequences.
- Creating environments in which students can safely communicate their own mathematical thinking is a crucial element in developing students' mathematical power.
- In a survey of Ohio science teachers, about half reported that they ask students to write explanations about what they observed in most or every lesson, while half report they do so in some or none of the lessons.[7]
- Oral and written communication about math is critical for learning to do math well. Communication and discourse do not take the place of learning

the basics of mathematics, however. Basic facts must be mastered and computational fluency achieved. Students must have methods they can use well and that produce correct answers. This skill is an essential underpinning of being able to communicate mathematically.[8]

Routes and Destinations

- Teachers can reinforce classroom communication skills and help students understand the value of focused conversation and writing when they:
  - Teach what is expected by sharing the norms and routines of communication.
  - Pose questions and tasks that elicit, engage, and challenge each student's thinking.
  - Listen carefully to students' ideas.
  - Arrange seating so that students can easily see classmates as they speak.
  - Encourage and monitor each student's communication and participation.
- Promoting classroom discourse demands that teachers be able to think quickly on their feet and make minute-by-minute decisions regarding:
  - When to join a group quietly without comment.
  - When to elaborate, provide information, clarify an issue, or model a problem.
  - When to let a student or group struggle with a difficulty.
  - When and how to attach appropriate mathematical notation and language to students' ideas.
- Students in the classroom should be involved in communication in which they:
  - Clarify and justify their ideas orally and in writing.
  - Think about a focus question individually before discussing it in class.
  - Provide an audience for their peers by speaking to, questioning, and listening to one another.
  - Write or discuss ideas with a partner before sharing with the whole group.
  - Seek clarification when they don't understand a question or statement.

Students develop proficiency in the language of mathematics through active use of that language in meaningful contexts.[9] Math teachers must promote students' ability to ask questions, share ideas, and communicate thinking in a dynamic environment of learning. Students who talk and write about mathematics as a way of making sense of the world are more likely to be able to use their own questions in the future to direct their learning and their work.

Adapted from *Minnesota K-12 Mathematics Framework,* SciMathMN, 1998

Endnotes

1. D. Davison and D. Pearce, "Using Writing to Reinforce Mathematics Instruction," *Arithmetic Teacher, 35*(8), 1988, pp. 42-45.
2. G. Lappan and P. W. Schram, "Communication and Reasoning: Critical Dimensions of Sense-Making in Mathematics," in P. Trafton and A. Schulte (Eds.), *New Directions for Elementary School Mathematics: 1989 Yearbook,* National Council of Teachers of Mathematics, Reston, VA, 1989.
3. L. D. Miller, "Teacher Benefits from Using Impromptu Writing Prompts in Algebra Class," *Journal for Research in Mathematics Education, 23*(4), 1992, pp. 329-340.
4. C. Dudley-Marling and D. Searle, *When Students Have Time to Talk: Creating Contexts for Learning Language,* Heinemann, Portsmouth, NH, 1991.
5. D. Dessart and M. Suydam, *Classroom Ideas from Research on Secondary School Mathematics,* National Council of Teachers of Mathematics, Reston, VA, 1983.
6. L. D. Miller, "Writing to Learn Mathematics," *Mathematics Teacher, 84*(7), 1991, pp. 516-521.
7. NCREL analysis of OMSC-sponsored teacher survey, fall 1999.
8. *Principles and Standards for School Mathematics: Discussion Draft,* National Council of Teachers of Mathematics, Reston, VA, October 1998.
9. F. Santiago and G. Spanos, "Meeting the NCTM Communication Standards for All Students," in G. Cuevas and M. Driscoll (Eds.), *Reaching All Students with Mathematics,* National Council of Teachers of Mathematics, 1993, p. 134. Note: The value of math discourse is that it supports and enhances the learning of math content and facts. Math discourse is of little value without acquiring mastery of math content.

The notion that mathematics is a set of rules and formalisms invented by experts, which everyone else is to memorize and use to obtain unique, correct answers, must be changed.

Thomas Romberg, 1992

Discourse and Questioning for Higher-Order Thinking

The National Council of Teachers of Mathematics indicates that classroom discourse about math, or "the ways of representing, thinking, talking, agreeing, and disagreeing" is central to helping students develop mathematical understanding and skills.[1] The development of higher-order thinking cannot be achieved without teachers asking a variety of questions to challenge students' thinking—questions that require more than factual recall. The time teachers allow for the students to formulate answers is also important.

Effective teacher questioning contributes significantly to student learning. Achievement improves when students are asked higher-level questions.[2] Unfortunately, higher-level questioning is not happening often enough in American classrooms.

Issues

- The research of Watson and Young found that teachers ask as many as 50,000 questions a year.[3] At least 80 percent of them require only simple, general recall of information.[4]
- Teachers ask questions of students at the rate of two or three per minute.[5] The period of silence that follows teachers' questions is often referred to as "wait time." Wait time is a key component in soliciting student responses to all forms of questions asked in class. A study of wait time found that if student replies were not given within *one second*, the questions were repeated, rephrased, or answered by someone else. If students did respond quickly enough, the teacher then replied immediately by asking another question or responding to the given answer.[6]

  When wait times were increased to *three seconds* or longer the following aspects of children's and teachers' conversations increased as well:

  - The length of student responses
  - The number of unsolicited, relevant responses from students
  - The number of student questions and the amount of speculative thinking
  - Student confidence
  - The use of evidence in student responses
  - The contributions by low-achieving students
  - The creativity of responses

- A *learning cycle* is a method of organizing instruction that closely resembles the way people spontaneously construct knowledge. It typically follows four stages, which are similar to the common lesson patterns of math teachers in Japan[7]:

    1. The teacher poses a complex task and asks questions that pique students' curiosity and motivate them.
    2. Students explore the problem alone, in pairs, or in small groups.
    3. The teacher pulls the students back together to summarize their findings.
    4. Students apply their learning to similar problems.

  American math teachers focus more on skill acquisition than on understanding:[8]

    1. The teacher instructs class in a concept or skill.
    2. The teacher solves example problems with class.
    3. Students practice on their own while teacher assists individual students.

- Researchers from the University of Wisconsin were among the first to demonstrate that students learn more at schools where the teachers adopt more "authentic" math and science teaching practices.[9] The cluster of practices the researchers brought to the schools included student-centered knowledge development; disciplined inquiry into and communication about learning; and explicit connections of student, learning, and the world outside school.
- Explaining the reasons behind math and science concepts and ideas happens too infrequently. About 20 percent of Ohio math and science teachers report that they explain the reasoning behind ideas in every math lesson they teach. Fifty percent claim they explain the reasoning most of the time and 30 percent only some of the time. Twelfth-grade teachers are the most likely to explain ideas most or all of the time.[10]
- Ohio math and science teachers are much more likely to ask older students to work on problems for which there is no obvious solution.[11]
- Teachers must be conscious of their questioning practices in order to plan effective ways to stimulate and develop student-thinking skills.[12] Of equal importance are the level of the question and a well-designed sequence of questions with a focus on student responses.

Routes

Many new curriculum projects, in both mathematics and science, reinforce the learning cycle concept in their teacher support materials. The investigative nature of the tasks, supported by the questioning skills of the teacher, helps students develop and refine their thinking skills. Teachers are encouraged to pose questions that ensure worthwhile student activity and lead students to explore a concept or explain their thinking.

Several types of questions have the capacity to increase the cognitive level of student responses and shift the environment from one of "show and tell" to one of inquiry and discussion:

- Reasoning questions require students to construct logically organized information, e.g., "How do you know?" "What would happen if...?"

- Open questions allow for more than one acceptable answer, e.g., “Tell us everything you notice about ...”
- Interpretive questions focus on applications, relationships, connections, or evaluations and lead students to analyze facts, e.g., “How would this be different if...”

Certain techniques have proven valuable for increasing student participation and learning. *Think-pair-share* is a teaching strategy that gives students the opportunity to reflect individually before sharing their thinking with a partner—or within a small group that then shares its ideas with the whole group, listening to, paraphrasing, and comparing other group solutions to its own. This process complements a learning cycle approach.[13]

The following strategies can help teachers improve the effectiveness of their interactions with students:

- Use precise language.
- Acknowledge all responses.
- Paraphrase student responses to acknowledge them.
- Rephrase questions rather than repeat them.
- Use nonspecific praise sparingly.
- Acknowledge student performance by giving specific feedback.
- Ask students to “think about their thinking.”
- Encourage students to ask questions of you and other students.
- Consciously plan for productive interaction
- Allow sufficient wait time after asking a question.

A relationship exists between the amount of wait time and the level of the question asked. Lower-level (fact-oriented) questions need shorter wait times than those requiring more thought from students. Moreover, as wait time increases, the number of higher-level cognitive questions that teachers ask increases as well. Some students are ready to respond quickly. They should be acknowledged, but wait time should not be curtailed. This will give more students the opportunity to engage in mathematical thinking.

Facilitating questioning and thinking skills in the classroom is an art that, with effort, develops over time. When teachers ask for explanations or follow-up responses, students have the opportunity to process and describe their own thinking. This process not only provides necessary support for student learning but also helps teachers assess student knowledge. Understanding student thinking provides necessary information for carefully planning follow-up questions and activities to move students’ learning forward.

Adapted from *Minnesota K-12 Mathematics Framework,* SciMath[MN], St. Paul, MN, 1998

Endnotes

1. *Professional Standards for Teaching Mathematics,* pp. 34, 37, National Council of Teachers of Mathematics, Reston, VA, 1991.
2. M. K. Prichard and S. Bingaman, "Instructional Activities and Decisions," in P. S. Wilson (Ed.), *Research Ideas for the Classroom: High School Mathematics,* p. 220, National Council of Teachers of Mathematics, Reston, VA, 1993.
3. K. Watson and B. Young, "Discourse for Learning in the Classroom," *Language Arts* 63, pp. 126-33, February, 1986.
4. N. Vacc, "Implementing the Professional Standards for Teaching Mathematics: Questioning in the Mathematics Classroom." *Arithmetic Teacher, 41*(2), pp. 88-91, 1993.
5. M. B. Rowe, *Teaching Science as Continuous Inquiry: A Basic,* McGraw-Hill Book Company, New York, 1978.
6. Ibid.
7. J. W. Stigler, P. Gonzales, T. Kawanaka, S. Knoll, and A. Serrano, The TIMSS Videotape Classroom Study: *Methods and Findings from an Exploratory Research Project on Eighth-Grade Mathematics Instruction in Germany, Japan, and the United States,* pp. 135-6, Washington, DC: U.S. Department of Education, National Center for Education Statistics, 1999.
8. Ibid.
9. This research is summarized in F. Newmann and G. Wehlage, Successful School Restructuring: *A Report to the Public and Educators by the Center on Organization and Restructuring of Schools,* Madison, WI: University of Wisconsin, 1995.
10. NCREL analysis of OMSC-sponsored teacher survey in Ohio, fall 1999.
11. Ibid.
12. M. Dantonio, *How Can We Create Thinkers?*, National Educational Service, p. 16, 1990.
13. A. E. Lawson, M. R. Abraham, & J. Renner, "A Theory of Instruction: Using the Learning Cycle to Teach Science Concepts and Thinking Skills," *Monograph of the National Association for Research in Science Teaching,* Cincinnati, OH, 1989.

"Knowledge and skills are of no use if the student cannot apply them in cooperative interaction with other people."

Circles of Learning, 1986

STRUCTURING COLLABORATIVE LEARNING

Group or cooperative learning has a long history in educational practice and has always been a part of a skillful teacher's repertoire. In a typical cooperative-learning situation in mathematics, students work on a problem in groups of two to five. They exchange views, discuss different approaches and solutions, and persuade each other of the soundness of their arguments. By explaining their ideas to others, students clarify their reasoning, order their thoughts, revise their strategies, and expand their conceptual understanding.

How Is Group Learning Best Used and How Is it Being Used Now?

- Effective cooperative-learning groups are structured to have shared leadership and to have both group and individual accountability for learning the material. Both factors provide incentives for students to help each other learn.[1]
- Cooperative-group structures provide learning opportunities that do not typically occur in traditional classrooms, including opportunities to resolve conflicting points of view.[2] They result in greater self-confidence, better group relations, more cross-cultural integration, and improved acceptance of mainstreamed children.[3] Small-group interaction helps students build the social skills necessary to work effectively on a team—skills that employers find valuable.[4]
- A review of the research reveals that 72 percent of cooperative-learning studies showed higher achievement for students involved in cooperative learning.[5]
- Learning experiences in small groups tend to produce higher results than individualistic or competitive learning situations, especially for more elaborated skills. This result is true for "all ages, subject areas, and for tasks involving concept attainment, verbal problem solving, categorization, spatial problem solving, retention and memory, motor performance, and guessing-judging-predicting. For rote-decoding and correcting tasks, cooperation seems to be equally as effective as competitive and individualistic learning procedures."[6]
- The Third International Mathematics and Science Study (TIMSS) revealed that 11 percent of all U.S. fourth-grade math teachers report having students work in small groups without direct teacher assistance most or all of the time. For eighth grade, the figure is 12 percent.[7] Comparable figures for science are 10 percent in Grade 4 and 11 percent in Grade 8.[8]
- In Ohio, 10 percent of third- and fourth-grade math teachers report that they have students work in small groups without direct teacher assistance most or all of the time. For seventh- and eighth-grade teachers the figure is 9 percent, and for twelfth-grade teachers it is 10 percent.[9]

- Ohio's figures for science are higher: 16 percent of third- and fourth-grade science teachers have their students work in small groups most or all of the time; 19 percent of seventh- and eighth-grade teachers reported the same; and 25 percent of twelfth-grade teachers use independent small-group learning most of the time.[10]
- A major review of studies of within-class ability grouping (creating groups within the classroom based on achievement) found that low-achieving students benefited from participating in groups that included higher-achieving students. Students of middle ability found more success in homogenous groups. For students of high ability, group composition had no effects. Overall, the results suggest that grouping students with similar abilities is only slightly more effective than using mixed groups.[11] One drawback in the use of groups is the "hitchhiker" problem, where certain students do the majority of the work. The hitchhiker shares in the success of the group without putting forth an equal amount of effort.
- Teachers in lower grades who spend more time per week with the same group of students than teachers in higher grades are more likely to use small-group instruction and to conduct classroom discussions about the classwork.[12]
- Teachers are seeking training in cooperative learning as an instructional strategy. In 1993-94, 50 percent of teachers reported they had attended a training session on cooperative learning since the end of the previous school year.[13] Teachers who participated in professional development on cooperative learning were more likely to use small-group instruction in class.[14]

Routes and Destinations

Teachers play a critical role in collaborative learning by forming groups, observing and interacting with groups, answering and clarifying questions, and moderating and helping students tie ideas together.[15] Teachers establish the guidelines and expectations for working cooperatively and must directly teach group-processing and interpersonal skills. Teachers who spend time explaining the reasons for cooperative group work and who do not grade on a curve encounter the hitchhiker problem less often.

The following are suggestions that may help make structured, cooperative lessons more effective:[16]

- Help students recognize that they must depend on one another to complete the task. "We sink or swim together."
- Emphasize face-to-face interaction among group members.
- Emphasize interpersonal and small-group skills.
- As a class, reflect on group processes.
- Emphasize and discuss individual accountability.
- To lessen the likelihood of the "hitchhiker" problem, explain the reasons for cooperative group work and do not grade tasks on a curve.

While cooperative learning is well-suited to a variety of instructional purposes, tasks that require multiple abilities and contributions for goal completion are likely to promote better cooperative activity and collaboration by all students in a group.[17]

For all students, cooperative, heterogeneous, and flexible groupings for instruction are more effective for stimulating and improving achievement than the traditional independent-learner approach. The teacher is instrumental in structuring "a pervasive norm in the classroom that helping one's peers to learn is not a marginal activity, but is a central element of students' roles."[18]

Adapted from *Minnesota K-12 Mathematics Framework,* SciMath^MN^, 1998

Endnotes

1. G. Cawelti (Ed.), *Handbook of Research on Improving Student Achievement,* Educational Research Service, Arlington, VA, 1995.
2. E. Yackel, P. Cobb, and T. Wood, "Small-Group Interactions as a Source of Learning Opportunities in Second-Grade Mathematics," *Journal of Research in Mathematics Education, 22*(5), pp. 390-408, 1991.
3. N. Kober, EDTALK: *What We Know About Mathematics Teaching and Learning,* Council for Educational Development and Research, Washington, DC, 1991.
4. R. J. Murnane and F. Levy, *Teaching the New Basic Skills: Principles for Educating Children to Thrive in a Changing Economy,* The Free Press, New York, 1996.
5. T. L. Good, C. Mulryan, and M. McCaslin, "Grouping for Instruction in Mathematics: A Call for Programmatic Research on Small-Group Process," in D. A. Grouws (Ed.), *Handbook of Research on Mathematics Teaching and Learning,* MacMillan Publishing Company, New York, NY, 1992.
6. D. Johnson, R. Johnson, and E. Holubec, *Circles of Learning,* Interaction Book Company, Edina, MN, 1986.
7. I. Mullis, M. Martin, A Beaton, et al., *Mathematics Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study,* TIMSS International Study Center, Boston College, Chestnut Hill, MA, 1997; A. Beaton, I. Mullis, M. Martin, et al., *Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study,* TIMSS International Study Center, Boston College, Chestnut Hill, MA, 1996.
8. M. Martin, I. Mullis, A Beaton, et al., *Science Achievement in the Primary School Years: IEA's Third International Mathematics and Science Study,* TIMSS International Study Center, Boston College, Chestnut Hill, MA, 1997; A. Beaton, M. Martin, I. Mullis, et al., *Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study,* TIMSS International Study Center, Boston College, Chestnut Hill, MA, 1996.
9. NCREL analysis of OMSC-sponsored Teacher Survey, fall 1999.
10. Ibid.
11. Y. Lou, P. Abrami, J. Spence, et al., "Within-Class Grouping: A Meta-Analysis," *Review of Educational Research, 66*(4), pp. 423-458, Winter 1996. Note that tracking and other versions of allocating educational opportunities differentially, which take place at the level of grade or school—not within the classroom, have negative consequences for all but the most gifted students. See J. Oakes and J. Goodlad, *Keeping Track: How Schools Structure Inequality,* Yale University Press, New Haven, CT, 1986.
12. R. R. Henke, X. Chen, and G. Goldman, *What Happens in Classrooms? Instructional Practices in Elementary and Secondary Schools 1994-95,* National Center for Education Statistics, U.S. Department of Education, Washington DC, 1999.
13. R. R. Henke, S. P. Choy, X. Chen, S. Geis, M. N. Alt, and S. P. Broughman, *America's Teachers: Profile of a Profession 1993-94,* National Center for Education Statistics, U.S. Department of Education, Washington DC, 1997.
14. Henke, Chen, and Goldman.
15. Kober, p. 14.
16. D. Johnson and R. Johnson, "Classroom Instruction and Cooperative Learning," in H. Waxman and H. Walberg (Eds.), *Effective Teaching: Current Research,* pp 279-281, McCutchan Publishing Corporation, Berkeley, CA, 1991.
17. P. A. Cohen, J. A. Kulik, and C. Kulik, "Educational Outcomes of Tutoring: A Meta-Analysis of Findings," *American Educational Research Journal, 19*(2), pp. 237-248, 1982.
18. E. Yackel, P. Cobb, T. Wood, G. Wheatley, and G. Merkel, "The Importance of Social Interaction in Children's Construction of Mathematical Knowledge," in T. J. Cooney and C. R. Hirsch (Eds.), *Teaching and Learning Mathematics in the 1990's: 1990 Yearbook,* p.20, National Council of Teachers of Mathematics, Reston, VA, 1990.

"What we assess and how we assess it communicates what we value."

National Council of Teachers of Mathematics, 1995

ASSESSING STUDENT PERFORMANCE

Assessment is not synonymous with evaluation and testing.

Assessment is the process of gathering information. Once the information has been collected, evaluation can begin. *Evaluation* is the process of interpreting and integrated diverse pieces of data into a summary judgment. *Tests* are measuring devices used to document student learning on narrowly defined questions and tasks. Educators have a tendency to reduce assessment to testing, often using data from a single test to indicate a student's capabilities. In reality, tests are just one of many tools available to the assessment process.

Assessment should be a feedback mechanism; it should show students what teachers expect. For example, if the process or strategies students use to arrive at a solution are as important as the solution itself, the teacher should select an assessment method that captures this information. If knowledge of certain facts or procedures is all that is required, a multiple-choice or short-answer test will suffice. Assessment should reflect both instructional goals and strategies.

Recent techniques—known as "alternative," "authentic," "active," and "performance" assessments—reflect new understandings of how students learn. Beyond mastering recollection of facts, these techniques focus on how students integrate and generalize knowledge and procedures. In fact, these techniques go beyond testing and help students gain a deeper understanding of the topic.

Issues

- As schools increasingly stress higher-order thinking skills and as the school-age population becomes more culturally and linguistically diverse, assessment tools must expand beyond multiple-choice or short-answer tests to measure the full scope of students' performance and progress accurately.[1]
- Once-per-year standardized tests, including Ohio's Proficiency Tests, are rich in data and can outline the general trends in the educational productivity of a state, district, or school. Yet, these tests are of limited use to individual teachers, who must make decisions about children and instruction every day of the school year. Thus, it is important to keep the purpose of a test in mind as you make decisions based on the data derived from the test.
- Determining end-of-year or end-of-semester grades is perhaps the most common use of the assessment information teachers collect. Teachers consider many factors when they determine student grades. While some rely only on the absolute level of student achievement, others consider additional factors such as the amount of effort or degree of improvement shown by their students. Most, however, use a mixture of these factors, assigning a higher level of importance to some than to others.[2]

- Research has found that many teachers misuse or ineffectively use traditional forms of assessment, including both commercial tests and teacher-developed instruments.[3]
- The knowledge and abilities of students from different cultural or linguistic backgrounds are not well measured by multiple-choice or short-answer tests or quizzes in English. Alternative forms of assessment, when implemented properly, can give teachers more useful information about what these children know and can do and what kinds of instruction will help them the most.[4]
- Use of homework as an assessment tool varies among teachers of different grades and subjects: 37 percent of primary-grade teachers in the U.S. report that they often collect, correct, and discuss homework, compared to 58 percent of intermediate-grade teachers, 53 percent of middle school teachers, and 50 percent of high school teachers.[5] Yet, 51 percent of mathematics teachers report that they often record only whether students complete a homework assignments.
- Portfolios are a popular assessment method: 49 percent of U.S. teachers say they play an important role in assessing student performance.[6] A portfolio is a collection of a student's work chosen to represent the student's progress in acquiring skills or conceptual understanding. Portfolios can be more or less formal, depending on the criteria involved in selecting and assessing the quality of the work. Portfolio assessment can include teacher-student conferences about selection and assessment of the work. Although they are not without controversy,[7] portfolios allow teachers to evaluate higher-order, complex skills while providing opportunities for student goal setting and self-evaluation.[8]

Routes and Destinations

When developing assessment tasks, first identify the "big idea" of a unit. What is worth knowing? Next, establish the criteria for judging student learning. Checklists are a useful way of displaying criteria and of clearly identifying the characteristics of a good product. Finally, give students access to the checklist as they prepare for and complete the assessment. The checklist not only will help students understand what is expected of them, it also will help them judge the quality of their work and allow them to discuss their progress with others.

Good assessment methods:

- Focus on what students know and can do rather than what they do not know.
- Match the curriculum in both *what* is taught and *how* it is taught.
- Are unbiased and fair for all students.
- Allow students to learn at various paces and honor various styles of learning and performance.
- Use questions that require thoughtful responses.
- Compare performance over time to help recognize patterns of success and difficulty.

Nearly any significant learning activity can provide an opportunity for informal assessment and can be modified to become a performance assessment task. Expanding the scope of assessment provides a broader view of student capabilities and knowledge. Teachers are better prepared to describe and comment on each student's learning to parents, administrators, and the students themselves. In addition, continual assessment of student understanding can guide both long- and short-range instructional decisions to:

- Ensure that every student is learning sound and significant mathematics.
- Support the development of a positive disposition toward mathematics.
- Challenge and extend student's ideas.
- Identify student needs in order to adapt or change activities.

Don't get discouraged if change doesn't occur over night. Making changes in classroom assessment practice is often time-consuming and sometimes frustrating. Teachers should keep in mind the following:[9]

- Don't try to do it all at once; start small but start somewhere.
- Don't try to do it all alone; find someone to work with, preferably at the same grade level or within the same discipline.

There is a dynamic interplay between instruction and assessment. Ideally, the lines between instruction and assessment become blurred when tests are part of instruction and instructional tasks are rich diagnostic opportunities.

Adapted from *Minnesota K-12 Mathematics Framework*, SciMath[MN], 1998.

Endnotes

1. J. L. Herman, P. R. Aschbacher, and L. Winters, *A Practical Guide to Alternative Assessment,* Alexandria, VA, Association for Supervision and Curriculum Development, 1992; G. Wiggins, "Assessment Authenticity, Context, and Validity," *Phi Delta Kappan, 75*(3), 1993, pp. 200-14.
2. S. Brookhart, "Teachers' Grading Practices: Meaning and Values," *Journal of Educational Measurement, 30*(2), 1993, pp. 123-42; R. J. Stiggins and N. F. Conklin, *In Teachers' Hands: Investigating the Practices of Classroom Assessment,* Albany, NY, State University of New York Press, 1992.
3. Brookhart, 1993; Stiggins and Conklin, 1992; C. Mertler, *Classroom Assessment Practices of Ohio Teachers,* paper presented at a meeting of the Midwestern Educational Research Association, Chicago, IL, October 1998.
4. M. W. LaCelle-Peterson and C. Rivera, "Is It Real for All Kids? A Framework for Equitable Assessment Policies for English Language Learners," *Harvard Educational Review, 64*(1), 1994, pp. 55-73.
5. R. R., Henke, X. Chen, and G. Goldman, *What Happens in Classrooms? Instructional Practices in Elementary and Secondary Schools, 1994-95,* Washington, DC, National Center for Education Statistics, 1999.
6. Ibid.
7. R. J. Shavelson, G. P. Baxter, and X. Gao, "Sampling Variability of Performance Assessments," *Journal of Educational Measurement, 30*(3), 1993, pp. 215-32; D. M. Koretz, B. M. Stecher, S. P. Klein, D. McCaffrey, and E. Deibert, *Can Portfolios Assess Student Performance and Influence Instruction? The 1991-92 Vermont Experience,* Santa Monica, CA, The RAND Corporation, 1994.
8. J. A. Arter and V. Spandel, "Using Portfolios of Student Work in Instruction and Assessment," *Educational Measurement: Issues and Practices, 11*(1), 1992, pp. 36-44; L. Darling-Hammond, "Performance-Based Assessment and Educational Equity," *Harvard Educational Review, 64*(1), 1994, pp. 5-30.
9. J. Stenmark (Ed.), *Mathematics Assessment: Myths, Models, Good Questions, and Practical Suggestions,* Reston, VA, National Council of Teachers of Mathematics, 1991.

MATH AND SCIENCE

"I finally figured out a way to test whether you have taught an idea or you have only taught a definition. You say, 'Without using the new word which you have just learned, try to rephrase what you have just learned in your own language. [For example,] without using the word 'energy,' tell me what you know now about a dog's motion.' You cannot. So you learned nothing except the definition. You learned nothing about science."

Richard Feynman, addressing the National Science Teachers Association, April 1966

STANDARDS

The performance of America's schools has steadily improved in recent decades.[1] Even so, when compared to achievement levels of many other nations, the U.S. continues to fall short, particularly at the end of secondary school.[2]

Educators now find themselves struggling with difficult questions. How do we teach more content, more effectively? How do we better prepare students for higher education and the workplace? And, as in Feynman's dilemma, how do we know that students have learned what we have taught?

The Emergence of Standards

Goals introduced at the 1989 National Education Summit were intended to make U.S. schools more internationally competitive.[3] The goals challenged states to set high and rigorous standards for all children. In response, all 50 states now have standards in place.[4] In addition, 47 states say they have statewide assessments that are aligned with their standards, and 27 states have aligned exit exams that students must pass to graduate high school. However, standards and benchmarks still vary widely across the nation.

Even the definition of *standards* is open for interpretation. Some believe requiring higher test scores is the answer. Others want to hold schools or entire districts accountable for the number of students who pass tests. Still others believe standards should be goals or guidelines that encourage higher productivity rather than require levels of achievement.

Should standards be set to compete with students of other countries? Should standards apply only in the core subject areas of math, science, history (or social studies), and geography? Should those who are unable to achieve the standards be penalized? How do we use standards to improve the education of all students, rather than just a handful?

The Value of Standards

- In poll after poll, the public strongly supports standards. However, polls tell us little about what the content of standards should be. "Basics first" is a common refrain and one the public often equates with a call for standards. However, "basics first" does not fit well with current research about teaching and learning.[5]
- Opinion polls also reveal that the public has extremely high expectations of their schools. For those expectations to be met, educators estimate that students need an additional 10 years of schooling beyond the typical K-12 pattern of school attendance.[6]

- Several years ago, a comparison was made of states' results on the National Assessment of Educational Progress (NAEP) and on their own assessments. A negative correlation was found: Most states with low NAEP scores had high proportions of students passing their own state test; most states with high NAEP scores had lower proportions of students passing their state test.[7]

What Do We Know About Ohio's Standards?

- Ohio has no mandated or approved statewide standards in place for curriculum or instruction for regular education students.[8] In 1997, standards were approved in principle by the Ohio State Board of Education and submitted to the Ohio Legislature for approval, but the legislature did not act on the proposal. Senate Bill 55, which was passed, incorporates some key elements of the proposed standards, including accountability and school improvement mandates.
- The Ohio Department of Education has prepared model curriculum documents in language arts, math, science, and social studies for school districts to use as guides in designing local curricula. These documents have been well received by various groups that evaluate state standards, including Achieve, Inc., the American Federation of Teachers, the Council for Basic Education, the Council of Chief State School Officers, *Education Week,* and the Fordham Foundation.[9]
- The "Learning Outcomes" that accompany the Ohio Proficiency Tests specify the objectives of the tests.[10] These learning outcomes are widely used by Ohio's elementary and middle schools to guide instruction.[11]
- The 27 performance standards of Ohio's school and district accountability system are now coming into full force, via Local Report Cards. Their impact on district and school decision making about curriculum content and instructional practice are not yet clear.
- The Ohio Board of Regents and Ohio Department of Education together prepared a set of "Common Expectations for Ohio's High School Graduates," which was released in October 1999. The document specifies general subject-area expectations and sets benchmarks for these expectations at Grades 4, 8, and 12. It covers math, science, English/language arts, social studies, the arts, foreign language, and lifelong learning.
- Ohio's accountability system establishes benchmarks and performance requirements based on pass/fail cut-off points on individual student test results. In this system, students who score high enough meet the standard. If enough of them do so, schools and districts reach their goals and are implicitly encouraged to continue teaching the same way. This system may support teachers who teach the memorization of facts, definitions, formulas, and other elements students will be asked to provide in order to pass the test. This type of teaching may improve test scores, but will it improve schools? Does it serve the purposes of education? The answer, according to the National Research Council, is probably not.[12]

Setting standards is easy. The real challenge is making them effective. The most important question then is how do we set standards that stimulate not just the achievement of the standards themselves, but deepen learning and understanding of math and science concepts as they apply to student's lives?[13]

Endnotes

1. Cf. the data presented in the "Learner Outcomes" section of J. Wirt, S. Choy, Y. Bae, et al., *The Condition of Education 1999,* National Center for Education Statistics, U.S. Department of Education, Washington, DC, 1999.
2. Ibid, pp. 32-33. For earlier but complementary data, see W. Elley, *How in the World Do Students Read? IEA Study of Reading Literacy,* The International Association for the Evaluation of Educational Achievement, Hamburg, Germany, 1992.
3. A. Beatty (Ed.), *Taking Stock: What Have We Learned About Making Education Standards Internationally Competitive?* National Academy Press, Washington, DC, 1997.
4. The data in this paragraph were collected as part of the American Federation of Teachers' continual survey of state standards. The phrasing of the AFT questions emphasizes a state's commitment. Hence, states that say they will have standards or assessments are counted alongside those that have them. The data may be reviewed at www.aft.org/edissues/standards99/toc.htm. A summary is available as American Federation of Teachers, "Making Standards Matter, 1999: An Update on State Activity," *Educational Issues Policy Brief, 11,* November 1999.
5. P. LeMahieu and W. Bickel, "The Public's and Policy Makers' Perspectives on Internationally Competitive Standards," paper prepared for a symposium sponsored by the Board on International Comparative Studies in Education, National Research Council, November 1996.
6. R. Marzano, J. Kendall, and L. Cicchinelli, *What Americans Believe Students Should Know: A Survey of U.S. Adults,* Mid-continent Regional Educational Laboratory, Aurora, CO, 1998.
7. M. Musick, *Setting Education Standards High Enough,* Southern Regional Education Board, Atlanta, GA, 1996.
8. Minimum high school graduation requirements, expressed in terms of subject credits, are, of course, mandated. These will become more challenging for the graduating class of 2002.
9. American Federation of Teachers, "Making Standards Matter 1999: An Update on State Activity," *AFT Educational Issues Policy Brief, 11,* November 1999; R. Blank, D. Langesen, M. Bush, et al., *Mathematics and Science Content Standards and Curriculum Frameworks: States Progress on Development and Implementation,* Council of Chief State School Officers, Washington, DC, 1997; R. Blank and E. Pechman, *State Curriculum Frameworks in Mathematics and Science: How Are They Changing across the States?* Council of Chief State School Officers, Washington, DC, 1995; C. Finn, M. Petrilli, and G. Vanourek, *The State of State Standard,* Thomas B. Fordham Foundation, Washington, DC, 1998; D. Hoff, "Standards at Crossroads after Decade," *Education Week,* September 22, 1999; L. Lerner, *State Science Standards: An Appraisal of Standards in 36 States,* Thomas B. Fordham Foundation, Washington, DC, 1998; S. Joftus and I. Berman, *Great Expectations? Defining and Assessing Rigor in State Standards for Mathematics and English Language Arts,* Council for Basic Education, Washington, DC, 1998; R. Raimi and L. Braden, *State Mathematics Standards: An Appraisal of Standards in 46 States, the District of Columbia, and Japan,* Thomas B. Fordham Foundation, Washington, DC, 1998; Regional Educational Laboratory Network Program, *A Summary of Analyzed State Curriculum Frameworks,* Mid-continent Regional Educational Laboratory, Aurora, CO, 1993; and W. Schmidt, "Preliminary Results of the Analysis of State Standards and Assessments," unpublished report for Achieve, Inc., January 1999.
10. The text of the Learning Outcomes is available on the Ohio Department of Education's Web site at www.state.oh.us/proficiency/ and from there selecting the grade-level test of interest.
11. NCREL analysis of OMSC-sponsored survey of Ohio schools.
12. J. Herbert and R. Hauser (Eds.), *High Stakes: Testing for Tracking, Promotion, and Graduation,* National Academy Press, Washington, DC, 1999.
13. The number of resources to assist standards building is growing. Two examples include: R. Marzano and J. Kendall, *A Comprehensive Guide to Designing Standards-Based Districts, Schools, and Classrooms,* Association for Supervision and Curriculum Development, Alexandria, VA, 1996; and M. Tucker and J. Codding, *Standards for Our Schools: How to Set Them, Measure Them, and Reach Them,* Jossey-Bass, San Francisco, CA, 1998.

[Physics teacher Norman Stonehouse] straightens the room at the end of class, and the students trickle out the door. The boys and girls talk animatedly, but not about gossip, or sports, or music. They talk about physics.

"A Day in the Life of Three Schools," Scientific American, October 1999

THE SYSTEM

INCENTIVES FOR LEARNING AND TEACHING

Classrooms are full of students who are unconvinced they need to be there, let alone do well in school. Without adequate motivation to study, take hard courses, and get good grades, students do just enough to get by. How does a teacher face the dual challenge of helping students learn and getting them to want to learn? How do we get both teacher and student to do better than they are doing now?

Recent studies of American high school students suggest that many see little reason to take school seriously:

- Over 50 percent of students say they could bring home grades of C or worse without their parents getting upset. Twenty-five percent say they could bring home grades of D or worse without upsetting parents.[1]
- Nearly 20 percent of students "do not try as hard as they can in school because they are worried about what their friends might think." Over one-third get through the school day primarily by "goofing off with friends."[2]
- Students in Beijing and Chicago were asked to rate the importance of effort and innate ability in influencing their performance at school. Students in both cities agreed that effort was "very important." However, American students rated the influence of innate ability much higher than did the Chinese.[3]
- To students, current college and university admissions policies appear to put more emphasis on SAT and ACT scores than on academic performance in high school. Students take separate tests for a high school grade, for graduation, for college admission, and for college course placement. The connections among them are not clear.

High school students with no intention of going on to college may be the most difficult to motivate. Why should they work hard in school when they can get a job without good grades?

- Companies that hire high school graduates rarely, if ever, ask to see transcripts or school records.[4]
- Among young adults who hold full-time jobs two years after graduation from high school, those who held a part-time job while in high school earn $250-$350 per month more than those who did not have a job while in high school.[5] High school grades have no relationship to earnings two years after graduation.
- Two-thirds of high school students are employed, and half work over 15 hours per week.[6] More high school youth are employed during the school year in the U.S. than in any other country.[7]

As education reform efforts place higher expectations on teachers to help reverse the disappointing performance of American students,[8] compensation for teachers lags behind those of other professions:

- Teacher salaries are lower than salaries for all of the following professions: Physicians; lawyers; electrical engineers; marketing, advertising, and public relations professionals; financial managers; computer systems analysts; education administrators; accountants and auditors; property and real estate managers; and food service and lodging managers.[9]
- In Ohio, the situation for beginning teachers is even more difficult. His or her salary is about $3,000 less per year than the national average.[10]

Routes and Destinations

The Education Commission of the States (ECS) recommends a set of incentives for students and teachers, including the following:[11]

Incentives for Students

- **Standards for graduation from high school**

  Recommendations include requiring students to take a larger core of academic classes and to achieve an aggressive minimum score on end-of-course exams or comprehensive exit exams before graduating. More challenging academic course requirements produce higher levels of academic achievement, both overall and among lower-performing students.[12]

- **Clear and specific requirements for admission to higher education**

  Clarifying standards and expectations could persuade students that academic performance in high school matters.[13]

- **Academic requirements for employment or apprenticeship programs**

  The National Alliance of Business (NAB) campaign *Making Academics Count* encourages companies of all sizes to ask applicants for high school records as part of the hiring process. Currently, 13,000 companies say they participate in the initiative. The NAB has set a goal of 20,000 by the summer of 2000.[14]

Incentives for Teachers

- **Goal clarification via mission, standards, and testing**

  Research shows that setting clear goals and standards for students helps and motivates teachers by giving them clear targets as well. In districts that have instituted these strategies, teachers report knowing for the first time in their professional lives where to focus their energies.[15]

- **Opportunities to work collaboratively at the school site**

  In any profession, workers are happier when they are involved in key decisions affecting their work environment. When school districts provide teachers with opportunities to participate in school organization, management, decision making, and leadership, teachers become more engaged and involved. They willingly work more hours on multiple tasks, while morale and enthusiasm increase.[16] When these opportunities focus on efforts to improve, real gains in teacher engagement and student learning are likely.

- **Incentives to increase knowledge and skills**

  Providing monetary incentives for teachers may motivate them to pursue the additional knowledge and skills necessary to work with more rigorous curricula.[17]

- **Incentives to improve student achievement**

  Some states and districts are offering salary bonuses to staff for raising student achievement to specific levels. "School-based performance awards" can focus teacher and school attention in areas of weak student performance.[18] Teacher contracts are beginning to reflect this relationship.[19]

Unfortunately, the scene in Mr. Stonehouse's physics classroom (described on the first page of this fact sheet) is not the norm in U.S. schools. Results from the Third International Mathematics and Science Study (TIMSS) show that American math and science students are being soundly outperformed by their counterparts from around the world.[20] Japanese high school students continue their tradition of strength in math and science, while Americans continue to lose ground. Interest and academic excellence in math and science are bred deep into Japanese culture. The opposite is true in the United States.

The seeds of apathy toward math and science education in America seem to be planted even before children arrive at school. When they do arrive though, how can we be sure they encounter a teacher with not only a wealth of math or science knowledge, but a passion for teaching it as well? If teachers aren't excited to be in the classroom, students won't be either.

Endnotes

1. L. Steinberg, *Beyond the Classroom*, Simon & Schuster, New York, 1996.
2. Ibid.
3. H. W. Stevenson and J. W. Stigler, *The Learning Gap*, Simon & Schuster, New York, 1992.
4. K. Larson, A. R. Guidera, and N. Smith, *The Formula for Success: A Business Leader's Guide to Supporting Math and Science Achievement,* Business Coalition for Education Reform, National Alliance for Business, Inc., U.S. Department of Education, Washington, DC, 1998.
5. NELS:88, National Center for Education Statistics, calculated by the Educational Testing Service Policy Information Center, *ETS Policy Notes,* Summer 1999.
6. Steinberg, 1996.
7. S. Takahira, P. Gonzales, M. Frase, and L., Salqanik, *Pursuing Excellence: A Study of U.S. Twelfth-Grade Mathematics and Science Teaching, Learning, Curriculum, and Achievement in International Context: Initial Findings from the Third International Mathematics and Science Study,* U.S. Department of Education, Washington, DC, 1996.
8. J. Wirt, S. Choy, Y. Bae, J. Sable, A. Gruner, J. Stennett, M. Perie, *The Condition of Education 1999,* U.S. Department of Education and the National Center for Education Statistics, Washington, DC, 1999.
9. B. Bruschi and R. Coley, *How Teachers Compare: The Prose, Document, and Qualitative Skills of American Teachers,* Educational Testing Service, Princeton, NJ, 1999, using data from the 1992 National Adult Literacy Survey.
10. National Center for Education Statistics, *Digest of Educational Statistics 1998,* U.S. Department of Education, Washington, DC, 1999.
11. Education Commission of the States (ECS), *A Policymakers' Guide to Incentives for Students, Teachers and Schools,* ECS, Denver, CO, 1997.
12. V. Lee, R. Croninger, and J. Smith, "Course-Taking, Equity, and Mathematics Learning: Testing the Constrained Curriculum Hypothesis in U.S. Secondary Schools," *Educational Evaluation and Policy Analysis, 19*(2), pp. 99-122, 1997.
13. ECS, 1997.
14. Larson, Guidera, and Smith, 1998.
15. H. G. Heneman III, "Assessment of the Motivational Reactions of Teachers to a School-Based Performance Award Program," *Journal of Personnel Evaluation in Education,* (forthcoming); C. Kelley, "The Kentucky School-Based Performance Award Program: School-Level Effects," *Educational Policy* (forthcoming); R. Elmore and D. Burney, *Investing in Teacher Learning: Staff Development and Instructional Improvement in Community School District #2, New York,* Columbia University, Teachers College and the National Commission on Teaching and America's Future, New York, 1997, as cited by ECS.
16. P. Wohlstetter, A. Van Kirk, P. Robertson, and S. Mohrman, Organizing for Successful School-Based Management, Association for Curriculum Development and Supervision, Alexandria, VA, 1997; ECS, 1997.
17. ECS, 1997.
18. Ibid.
19. L. Olson, "Pay-Performance Link in Salaries Gains Momentum," *Education Week,* Oct 13, 1999; "East Aurora District 131," Chicago Tribune, Oct 8, 1999.
20. J. W. Stigler and J. Hiebert, *The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom,* The Free Press, New York, NY, 1999.

Interviews with education leaders and policymakers in both states uncovered striking and unexpectedly similar stories.

National Education Goals Panel, 1998

The System

Paths to Success: Lessons Learned in North Carolina and Texas

Each year, the National Education Goals Panel (NEGP) tracks and reports on each state's progress in improving education for its children. The report is based on many factors including student scores on tests of the National Assessment of Education Progress (NAEP). In the panel's 1997 report, North Carolina and Texas stood out from all other states by showing significant improvement in the greatest number of areas.

Both states posted measurable, sustained gains in academic achievement, including the largest average increases in student math and reading scores on NAEP tests over a seven-year period. In particular, the scores of disadvantaged students improved more rapidly than those of advantaged students. These results were obtained not only in NAEP scores, but in the states' own assessments as well.

The panel commissioned Dr. David Grissmer, an educational researcher at the Rand Corporation, to uncover how North Carolina and Texas achieved these results. His analysis is worth noting not only for what he found, but for what he didn't.

Factors That Might Explain Their Success...But Don't

Grissmer first examined several common factors associated with student achievement. None of them appeared to affect the results in North Carolina and Texas:

- *Per-pupil spending:* Both states are below the national average.
- *Class size:* Both states are near the national average.
- *Percentage of teachers with advanced degrees:* Both states are below the national average.
- *Years of teacher experience:* Both states are below the national average.

Parallel Paths to Success

The study concluded that the most likely explanation for gains in North Carolina and Texas was the remarkably similar way in which each state set new education policy:

- Both states pursued similar policies to achieve goals in education.
- Both states effectively changed the organizational environment.
- Both states effectively changed the incentive structure for educators.

Though similar sets of education policies exist in other states, the successes in North Carolina and Texas can be traced to the way in which policies were developed, implemented, and sustained: through consistent, determined cooperation among educators, business leaders, and policymakers.

There were seven striking similarities between the two states:

1. **Leadership From the Business Community**

   In both states, the business community played a critical role in developing and sustaining reform. Business leaders helped form the strategic plan for improvement, forging compromises with the education interests and enabling passage of the necessary legislation. Business interests in both states worked to assure that the plans defined clear results and advocated increased flexibility for educators in how prescribed results were to be achieved.

2. **State Standards With Clear Teaching Objectives at Each Grade Level**

   Statewide academic standards were developed and adopted in both states in the late 1980s and early 1990s and were supported consistently thereafter. Standards were set for each grade and in several subjects. Teachers in all grades were given clear objectives for what students should know. In both states, efforts were made to align textbooks and curricula with the statewide standards. Both states emphasize that their academic standards apply to *all* students. Disadvantaged students are held to the same standards as advantaged students.

3. **Statewide Assessments Closely Linked to Academic Standards**

   New statewide assessment tests were developed in both states to reflect the academic standards for each grade. Assessment in both states is done in third through eighth grade in reading and math. Statewide testing to these standards began in Texas in 1993–94 and in North Carolina in 1992–93. The standards and assessments have remained substantially unchanged since that time.

4. **Data Systems for Continuous Improvement**

   Scores on the tests are provided to students, parents, teachers, schools, and school districts. Both states have a well-designed computerized system for storing the testing information and provide access to it in various ways for teachers, principals, and school districts. Access to school-level results is provided on the Internet in both states. Teachers in both states have access to summaries and individual data of students entering their classes each year. In both states test items are made available to the public after each test.

5. **Increasing Flexibility for Administrators and Teachers**

   The strategic plans developed in each state in the late 1980s and early 1990s acknowledged that teachers and administrators could not be held accountable unless they were given authority and flexibility to determine locally how to meet the standards. In both states, unnecessarily restrictive statutes governing schools and teaching were repealed. Constraints placed on district superintendents and principals for how money is spent were reduced. The policy objective was to allow local schools to vary the approaches they could take to achieve the standards.

6. **Accountability Systems With Consequences for Results**

   Both states reward schools financially for improved performance and have the power to disenfranchise school districts and remove principals based on sustained levels of poor performance. The two state systems take into account both absolute test scores and gains.

Schools are rated on scales ranging from exemplary to poor performing. The gain score is used as the primary ranking mechanism, but schools can be penalized if they do not have a specified proportion of students reaching a minimum proficiency level.

Both state systems show awareness of factors that could provide unfair advantage to certain schools, including the social and economic advantages of the school community. Care is taken in both states to account for students coming in during the year and to adjust beginning gain scores to the actual students in the schools at the beginning of the year. Both states keep close scrutiny of the students not taking tests. Thus the procedures—although not perfect—are designed to account for schools' special circumstances and to protect against manipulation by teachers or principals.

7. Shifting Resources to Schools With More Disadvantaged Students

Both states gradually shifted resources to schools with more disadvantaged students. This shift was partially the result of judicial decisions requiring the states to fund school districts more equitably. However, the shift may be an essential element of achieving a system perceived to be fair and equitable by teachers and administrators. The acceptance, endurance, and effectiveness of these policies may rest upon the perception that the distribution of resources among schools and school districts is fair and equitable.

Many of these reforms were initially opposed by the education community including representatives of school boards, principals, and teachers. In both states, the business community formed and funded new organizations representing the business, education, and policymaking communities: the North Carolina Public School Forum and the Texas Business-Education Coalition. These coalitions provided a forum to discuss education reform issues and forge compromises among the concerned groups to allow them to cooperate in support of subsequent legislation.

Both states also developed a cooperative infrastructure for supporting sustained and continuing improvement in education. Jointly funded with a mix of public, nonprofit, and private sector participation, this infrastructure includes:

- State-focused research institutes and centers
- Organizations devoted to research-based policy formulation
- A network of business-school system partnerships
- A variety of private sector "cottage industries" aiding school improvement with new systems and training methods

The components of this infrastructure work cooperatively to find innovative ways to improve schools and other support systems for children. They continually analyze and evaluate the results of their previous efforts.

Developing these systems in both states was a long and arduous process. However, the success of both states has proven that sustained cooperation among business leaders, educators, and policymakers can indeed improve education.

Adapted from D. Grissmer and A. Flanagan, *Exploring Rapid Achievement Gains in North Carolina and Texas*, Washington, DC: National Education Goals Panel, November, 1998; and E. Wurtz, *Promising Practices: Progress Toward the Goals: 1998,* Washington, DC: National Education Goals Panel, 1998.