

Best Practice

“There is little we do in America that is more important than teaching. Effective teaching of mathematics requires appropriate pedagogical and mathematical foundations, but thrives only in an environment of trust which encourages leadership and innovation. In short, teaching must become more professional.”
National Research Council, 1989.

Chapter 2

Introduction

One distinguishing characteristic of a profession is a body of specialized knowledge on which to base practice. It is only recently that the education profession has become more research-based in an attempt to inform and support teacher behavior and decision making. A research-based rationale for instructional practice is imperative if we are to counter the popular, but mistaken, notion that teaching requires no specialized knowledge (Clough, 1992).

“Pedagogical content knowledge differentiates expert teachers in a subject area from subject area experts.”

Cochran, 1992

Shulman (1986), in a study of teaching, found that knowledgeable and skilled teachers possess and use a comprehensive and synthetic kind of professional knowledge. Shulman labeled this knowledge as “pedagogical content knowledge” which includes the special understandings and abilities that skilled teachers use in their efforts to help students understand complex ideas. Pedagogical content knowledge integrates content knowledge in the discipline with content knowledge about teaching. It also incorporates understanding of content, curriculum, learning, and teaching so that teachers can make effective decisions about learning outcomes, curriculum materials, teaching strategies, and assessment tasks.

Professional knowledge is a key component for teachers as they reexamine their beliefs and revise their practice to meet the reform challenges in mathematics education. The vision of reform and the belief that all students can and should become “mathematically powerful” is supported by the *Minnesota Graduation Standards* and the National Council of Teachers of Mathematics (NCTM) *Curriculum and Evaluation Standards for School Mathematics*. Mathematical power includes the development of self-confidence and the ability to explore, conjecture, reason logically, and use a variety of mathematical methods to solve complicated real-world problems (NCTM, 1989, p. 5). Supporting mathematically powerful students requires:

- developmentally appropriate content based on important mathematics
- flexible instructional practices that encourage mindful and enduring learning by all students
- assessment practices that provide feedback on student progress and instructional effectiveness

“Teachers who begin to base their practice on [these] principles...should not expect to develop a finished repertoire of behaviors that, once achieved, will become routine. There is no point of arrival, but rather a path that leads to further growth and change.”

Schifter, 1996

This chapter focuses on “best practice,” the synthesis of research-based instructional strategies aimed at improving mathematics learning for all students. Central to best practice is research concerning how children learn mathematics. The chapter, therefore, begins with the theoretical foundation which makes the case for the importance of active, engaged learning and the necessity of aligning assessment with curriculum and instruction. The chapter then presents eight important best practice strategies. Though presented separately, the instructional strategies cited in this chapter are intended to be complementary, not mutually exclusive. Finally, to support the ultimate goal of improved mathematical learning and outcomes, the chapter ends with a section on reaching all students.

The information in this chapter is intended to broaden, but not to dictate, instructional practice. It describes some of the research on which best practice strategies are based and implications for instruction. This chapter also provides some jumping off points for looking critically at teacher practice, with the understanding that professional development and support are key to implementing instructional changes. It is hoped that the information on best practice in this chapter will encourage teachers to:

- form study groups to investigate best practice strategies in greater depth
- seek professional development opportunities to improve instructional strategies

"We must be impatient enough to take action and patient enough to sustain our efforts until we see results."
NCTM, 1996

- organize peer coaching and classroom observations to inform and support their implementation of best practice
- conduct research in their classrooms
- support change in the classroom, department, school, district, and system

This chapter does not cover all best practice strategies nor does it cover them in the depth or breadth of a thorough review. Resources that contain more information are listed at the end of each topic discussed. These were chosen because of their ability to provide rich and productive leads into educational research and literature as well as their accessibility. The list of cited references is included at the end of the chapter.

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Part 1 • Focusing on the Learner

“Tell me, I forget.

Show me I remember.

Involve me, I understand.”

Chinese proverb

Focusing on the Learner

Brain Research

"It is difficult to understand the brain because, unlike a computer, it was not built with specific purposes or principles of design in mind."

Fischbach, 1992

Developments in molecular biology, behavioral studies, endocrinology, and imaging technology have allowed researchers to literally see what is happening inside the brain while it works. This research, coupled with developments in cognitive psychology, has resulted in a growing interest in what is referred to as brain-based learning. This phrase is a way of pointing out and emphasizing that there should be a relationship between what we know about how the brain works and how children can learn best (Caine, 1997).

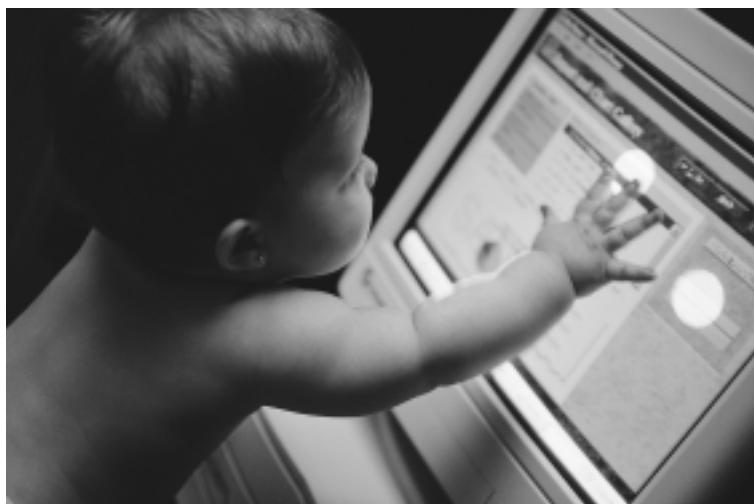
Not many years ago the brain was viewed as rule-bound, hard-wired, preset and fixed—more or less like a tape-recorder, storing whatever it heard, saw, tasted or felt. Research in the past decade has shown that, although the basic structural features of the brain are determined by genes, it is the environment that provides the necessary stimulation for the brain to achieve its potential. Nature and nurture must work together.

Brain research provides important information that can impact classroom instructional strategies:

- The brain is the ultimate hard-working athlete. The harder it exercises, or is used, the more "in shape" it appears to be as measured by the number of neurological connections found. Nerve connections (synapses) that are not strengthened by continuing stimulation from the environment die off.
- The brain is a pattern-seeker that requires external stimulation. Learning experiences should be designed to help learners identify patterns which facilitate connections with or modifications of previously learned patterns. Curriculum should be chosen with care and should emphasize the important interrelationships among the content and processes of mathematics.
- The brain connects emotion and cognition, therefore the classroom environment should be one that instills learners with confidence and is non-threatening. Work should be appropriately challenging and should teach students that they are not helpless, but rather are capable of exerting control over their learning.

"The brain is the ultimate 'use it or lose it' machine."

Kotulak, 1996



Cognitive Psychology Research

For most of this century, educational practice has been driven by behaviorism, a theory about how humans learn. Behaviorism assumes that students are blank slates (*tabula rasa*) on which the knowledge of others is simply written. Teaching based on behaviorism is characterized by:

- behavioral objectives
- tightly sequenced curricula
- drill and practice
- an emphasis on facts and principles
- an assumption that through mastering a series of simple steps, students are then able to engage in higher order thinking

Recent research in cognitive psychology has led to a theory of learning known as constructivism. Constructivism is deeply rooted in the work of a number of researchers, including Piaget, Dienes, and Bruner. It is the learning theory that forms the basis for instructional recommendations in this *Framework*.

The central tenets of constructivism are these:

- Humans are not blank slates, but rather they are makers of meaning. Individuals learn by actively constructing and reconstructing their own knowledge about how the world works.
- Humans learn by modifying old ideas, not simply by accumulating new ones. Learning involves a give-and-take between what we know or believe about something and new information. This process is a continuous one.
- Learning is mental work—it isn't always fun. It often includes periods of feeling perplexed, frustrated, and sometimes even angry.
- New understandings are both personally and socially constructed or negotiated. Our social and cultural interactions influence the way we make sense of the natural world.
- While we can explain things to others, we cannot understand it for them.
- Students make their own sense out of new information whether we like it or not. "When students cannot readily assimilate new data into existing mental structures, they construct new relationships or schema in order to accommodate the new knowledge" (Stiff et al., 1993, p. 7).

"It is important to understand at the outset that constructivism is not an instructional approach; it is a theory about how learners come to know."
Airasian & Walsh, 1997

Making Teaching Decisions Based on How Children Learn

Teachers must make decisions about the content and instructional strategies which best support student learning. Cognitive psychology provides the major theoretical rationale for the promotion of active student involvement in the learning process. It is at least as concerned with how children learn as with what they learn (Post, 1992, p. 20).

"The curriculum is a 'mind-altering device.'"
Eisner, 1997

- When learning is viewed as a continuing process of construction-reconstruction, learning tasks require an ongoing pattern of organization and reorganization. Curricula must deal directly with a few important ideas that are progressively sequenced.
- The construction of new knowledge takes time and sufficient experiences in a variety of contexts. This argues for a focused, coherent curriculum. Constructivism lends considerable support to the contemporary slogan that "less is more," the assertion that it is better to learn fewer things well than many things poorly.
- To make sense of the learning environment, students must be actively engaged. Learning must be "hands-on/minds-on."
- Because most learning is a social process, active involvement must be accompanied by students' interpretation and explanation of their findings. Students must have opportunities to explicitly share their ideas with other students, reflect on similarities and differences between these ideas, and revise their ideas and solutions as necessary.

Constructivist classrooms are not places where all ideas about mathematics are equal or where students vote on ideas and explanations. Constructivism requires teachers to intervene, not by saying to a student, "that's wrong," but by posing or presenting questions, activities, demonstrations, or investigations that help students reconsider their ideas as they develop and refine their understanding. In order for this to happen, a classroom environment must exist in which all members accept various strategies, encourage respectful listening, and welcome argument around mathematical understanding. In a constructivist classroom, teachers:

"In reality, no one can teach mathematics. Effective teachers are those who can stimulate students to learn mathematics."
National Research Council (NRC), 1989

- view students as thinkers with emerging theories about mathematics
- value and actively elicit student questions
- seek the students' points of view in order to assess their understanding
- rely heavily on primary sources of data
- generally behave in an interactive manner, mediating the environment for students



Providing Opportunities for Active Student Engagement

Brain research supports cognitive psychology theory and validates what good teachers have always known. Active engagement creates the brain activity fundamental to the learning process. Robust learning requires a change in the learner. Neurological connections are made and reinforced by what the learner does—what he or she attends to, the activities in which he or she engages.

“The learner must have experience with hypothesizing and predicting, manipulating objects, posing questions, re-searching answers, imagining, investigating and inventing.”
Fosnot, 1993

In mathematics classes focused on providing a hands-on/minds-on environment, students:

- use mathematics to communicate their own thinking about complex situations with pictures, diagrams, graphs, words, symbols, and numerical examples
- solve problems using a variety of mathematical models and tools, such as manipulatives, calculators, and computers
- do projects and activities
- share and critique their own and others’ mathematical ideas and products
- are thoughtful, persistent, flexible, self directed, and confident

The quality and durability of students’ learning depends in part on the complexity of the tasks they encounter, the time students are given to make sense of their ideas, the flexibility of teachers in meeting student needs, and the connections that are made among equivalent representations of the same concept. Heibert (1996) reports that in classrooms emphasizing a conceptual approach to mathematics, tasks were chosen which make mathematics problematic for the student, connect with where students are mathematically, and leave students with something of mathematical value. Good tasks are ones that do not separate mathematical thinking from mathematical concepts or skills, that capture students’ curiosity, and that invite them to speculate and to pursue their hunches (NCTM, 1991).

Mathematics is built from human activity—sorting, counting, ordering, comparing. From a young age children are naturally interested in mathematics and gradually develop a complex set of informal ideas about quantity in the natural environment. Effective instructional practices help learners reshape and internalize new information to make sense of the mathematics presented to them. As learners interact with new ideas and situations, they produce more complex knowledge based on their experiences and views of the world (Confrey, 1990, p. 109).

A major goal of both constructivism and the *Minnesota Graduation Standards* is to create autonomous learners. Students who come to know science and mathematics as a way of acting on, exploring, and understanding their world are more likely to be able to find a place in it that allows them to use their full capabilities. Classrooms must promote the abilities of students to initiate and sustain continuous inquiry. Such classrooms then become mathematical communities where students exchange ideas and learn concepts by talking, exploring, discovering, and thinking about their work.

Analyzing Student Learning to Improve Instruction

Active learning demands active assessment. “The emphasis on construction forces us to probe deeply into students’ activity. How firm a grasp do they have on the material? What can they do with it? What misconceptions do they entertain? Even if they are producing wrong answers, are they constructing in a way that is mathematically recognizable? These are among the questions we need to ask in order to teach effectively” (Noddings, 1990, p. 14). The Mathematical Sciences Education Board (MSEB, 1993, p. 1) presents three educational principles that form a foundation for assessment that can support effective education:

- **Content**—Assessment should reflect the mathematics that is most important for students to learn.
- **Learning**—Assessment should enhance mathematics learning and support good instructional practice.
- **Equity**—Assessment should support every student’s opportunity to learn important mathematics.

Assessment is a communication process that tells teachers, parents, and students what is important to learn and what students already know and can do. Mathematics assessment must be aligned with curriculum and instruction to provide students with opportunities that are rich in breadth and depth and promote deep mathematical understanding.

Traditionally, mathematics instruction and assessment have been organized in ways that underestimate the mathematical capability of most students, thereby unintentionally filtering out students from further study of mathematics (NCTM, 1995, p. 1). Teachers need to find out what students know and think about a concept prior to selecting the context for instruction. Using careful observations and asking key questions while students interact with the problem at hand are important for guiding student thinking. Subsequent teaching can then move the child from his or her present level of understanding to the next.

During and following instruction, it is important to assess students’ abilities to:

- use mathematical processes, such as computation, in the context of many kinds of problems rather than in isolation
- use mathematics to make sense of complex situations
- work on extended investigations
- formulate and refine hypotheses
- collect and organize information
- explain a concept orally or in writing
- solve problems that reflect those encountered in real life

All learning activities are not equally worthwhile. The same can be said of assessments. They should mirror real-life skills and knowledge, represent instructional practice, document what students know and can do, and provide feedback about the quality of curriculum, instruction, and achievement.

For Further Study of Topics in Part I

Brooks, J.G. & Brooks, M.G. (1993). *The case for constructivist classrooms*. Alexandria, VA: Association for Supervision and Curriculum Development.

Clements, D.H. & Battista, M.T. (1990). “Constructivist teaching and learning.” *The Arithmetic Teacher*, 38(1), 34-35.

Kotulak, R. (1996). *Inside the brain*. Chicago, IL: Andrews and McMeel.

Webb, N. & Coxford, A. (Eds.). (1993). *Assessment in the mathematics classroom: 1993 yearbook*. Reston, VA: NCTM.

“In the constructivist approach, we look not for what students can repeat, but for what they can generate, demonstrate, and exhibit.”
Brooks & Brooks, 1993