



BEST PRACTICE

Today's Standards for Teaching and
Learning in America's Schools

Third Edition

Steven Zemelman, Harvey Daniels, and Arthur Hyde

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Preface: Welcome to the Third Edition

This is a book about excellent teaching and powerful learning. Its principles come from authoritative and reliable sources—the major professional organizations, research centers, and subject-matter groups in American education. Its recommendations draw upon scientific research of rigorous design, both experimental and qualitative. The classroom stories woven through the book come from some of the country’s most accomplished teachers. And the practices endorsed here have proven their effectiveness with students from kindergarten through high school, across the curriculum, and among learners of diverse languages, abilities, personalities, and learning styles.

In these fundamental ways, the third edition of *Best Practice* is very much like the two previous ones. And, as you would expect, we’ve completely revised and updated the book: we’ve reviewed the newest scientific evidence on effective teaching practices, shown how the standard of proficient teaching is evolving in every major teaching field, and added new classroom stories from several different states.

But since this book began its life, the school world has also changed in important, sometimes worrisome ways. For one thing, the term *Best Practice* itself has suffered from “terminology drift,” a process by which useful educational ideas become overly popular, are carelessly used, and come unmoored from their original meanings. When we see “Best Practice worksheets” being sold at professional conferences, and tucked into free “Best Practice” tote bags, we get worried.

We’re also concerned about the changing meaning of the term *standards*. When we wrote the first edition of this book in 1993, the three of us were pleased to be part of the newborn “standards movement” in education. Today, we’re not so sure. Now, under the banner of “higher standards,” forty-nine of the fifty states have developed their own often-idiosyncratic system of frameworks, targets, benchmarks, rules, and, above all, *tests* for both students and teachers. It’s unfortunate. A movement that began as a sincere attempt to provide all children with first-rate teaching has mutated into a

contentious, costly battle that has left everyone—kids, parents, teachers, school administrators, and the taxpaying public—bruised and confused.

Indeed, today's school reform conversations have become both so polarized and so muddled that we were briefly tempted to leave the word *standards* out of the book's title altogether this time around. But, of course, the opposite is needed. The language of school improvement needs clarification and defense now more than ever. If terms are being co-opted and misused, the abuse needs to be challenged, not winked at. So we want to begin this third edition by clarifying and affirming what the terms *standards* and *Best Practice* mean to us and to the teaching profession, and how they are evolving amid the political battles raging through education today.

WHAT DO WE MEAN BY "BEST PRACTICE"?

The expression "best practice" was originally borrowed from the professions of medicine, law, and architecture, where "good practice" or "best practice" are everyday phrases used to describe solid, reputable, state-of-the-art work in a field. If a professional is following best practice standards, he or she is aware of current research and consistently offers clients the full benefits of the latest knowledge, technology, and procedures. If a doctor, for example, does not follow contemporary standards of medicine and a case turns out badly, peers may criticize his decisions and treatments by saying something like, "that was simply not best practice."

Until recently, we haven't had an everyday term for state-of-the-art work in education. In fact, some veteran teachers would even *deny* the need for a current, research-based standard of instruction. "I just give 'em the basics," such teachers say, "It's worked just fine for thirty years, and I don't hold with any of this new mumbo-jumbo." One wonders how long such self-satisfied teachers would continue to go to a doctor who says: "I practice medicine exactly the same way today that I did thirty years ago. I haven't changed a thing. I don't pay any attention to all that newfangled stuff."

Some people insist that education as a field does not enjoy the clear-cut evolution of medicine, law, or architecture. But still, if educators are people who take ideas seriously, who believe in inquiry, and who subscribe to the possibility of human progress, then our professional language must label and respect practice that is at the leading edge of the field. So that's why we have imported (and capitalized) the term *Best Practice*—as a shorthand emblem of serious, thoughtful, informed, responsible, state-of-the-art teaching.

As you'll learn in the following pages, there is a strong consensus among the seemingly disparate subject-matter fields about how kids learn best. Virtually all the authoritative voices and documents in every teaching field are calling for schools that are more student-centered, active, experiential, authentic, democratic, collaborative, rigorous, and challenging. That's the short definition of Best Practice teaching; the rest of the book will deepen that description. But this isn't the only definition of standards around; indeed, there's a contrary, competing paradigm, one that's increasingly impinging on the lives of teachers, children, and parents.

THE DOUBLE STANDARDS MOVEMENT

Most teachers don't like the standards movement. Don't believe us? Just bring up the topic of standards with a roomful of teachers and watch what happens. Their faces immediately take on the expression of one of Dracula's about-to-be victims in those old horror movies. You half expect them to start making defensive crosses with their fingers and tossing garlic bulbs at you. What happened? How did *standards* become a dirty word—or at least one that invokes wildly mixed feelings among educators?

Back in the late 1980s, establishing curriculum standards sounded like a good idea. Wouldn't it be great if each subject taught in school (language arts, science, mathematics, history, the arts) had its own clear-cut descriptions of what to teach and how to teach it? These recommendations could be based on a meta-analysis of the latest research in the subject, consultations with top experts and theorists, and systematic reviews of pedagogy and practice. The National Council of Teachers of Mathematics was the first professional organization to attempt this process, when in 1987 it outlined a challenging curriculum that stressed math as a way of thinking and required new, highly interactive teaching strategies. The NCTM Standards were welcomed by teachers, school reformers, and politicians alike, and the idea quickly spread that every school subject field should develop parallel documents. With initial funding from the U.S. Department of Education, a dozen other professional organizations were eventually commissioned to develop similar standards for their own fields.

Trickling in over the next several years, the outcomes were uneven and asymmetrical. Some standards reports specified the content to be mastered in minute detail; others kept to broad guidelines. Some gave careful attention to teaching methodology; others hid it in the background. A few reports

frontally addressed issues of access and equity, while most simply assumed that all children would have equal opportunities under new standards. Almost all the commissioned groups used their standards documents to lobby for more money, personnel, and classroom time for their own subjects, at the expense of others. Former Department of Education official Chester Finn was not far wrong when he noted the standards-setters' "gluttonous and imperialistic tendencies."

But however disparate and self-serving, the results also held a consensus. All the standards documents rejected schooling as usual. All called for classrooms filled with challenging, authentic, and collaborative work—a big break with past practice. They repudiated the coverage model of curriculum, where students go one inch deep in a thousand topics, and instead urged deeper exploration of a smaller number of subjects. In a word, these national curriculum standards, developed by the mainstream professional organizations in each field, contained a strong endorsement of progressive teaching methods and constructivist learning theory. And these standards, it is important to remember, emerged from *within* the profession. We teachers saw these as *our* standards, developed inside our profession, based on our research, and enunciated by our subject-matter experts and top practitioners, just the way best practice standards are developed among doctors, lawyers, and other professionals.

Meanwhile, outside the teaching profession, another standards movement was developing. Spurred by business groups, school privatization enthusiasts, conservative think tanks, and culture-wars pundits, the state governors and legislatures embarked on their own standards-building projects. Sometimes the states began by accepting the premises of the national curriculum standards; others started fresh. Almost all subscribed to the more-is-better school of rulemaking, generating hundreds of standards, targets, benchmarks, goals, and procedures. The resulting mandates undermined classroom practitioners' autonomy and professionalism in a variety of ways. Teachers were increasingly told by their states what to teach, when to teach it, and how—often in pre-scripted, word-for-word, "teacher-proof" programs that not only ruled out teachers' creativity, but their humanity as well. Across the country, teachers were forced to post outside their classroom doors, in arcane code, which among thousands of state standards (e.g., Reading, C.4.viii.23) they were meeting at each minute of the school day.

But the worst was the testing. By the time they were done, most states had linked their newly created curriculum frameworks to testing systems that deeply contradicted the national curriculum standards. Across the country, state tests (with a few notable exceptions that we'll celebrate in this book) predominantly favored multiple-choice, factual-recall formats that pushed teachers right back toward a superficial curriculum of coverage and time-eating test-prep. Arbitrary "cut scores" publicly labeled individual kids, ethnic groups, whole schools, and increasingly, individual teachers as "failures." States required that these often-misleading findings be published as "school report cards," which naturally became fodder for local editorial pages and stock-in-trade for competing real estate agents. In Chicago, we've now attained the apotheosis of accountability: many of our most affluent, even elite suburban schools have been placed on the state "watch list" because of technicalities, mistakes, or anomalies in complying with various accountability standards. Perhaps experiences like these explain why teachers react like vampire victims when the word *standards* comes up.

So we have two, mostly contradictory standards movements afoot in the land, and the accountability advocates currently have the loudest voice. These reformers retain their laserlike focus on systems of high-stakes testing and accountability, linked to elaborate rewards and punishments for students, teachers, schools, and districts. Though wary that federal tests might undermine local authority, these standards-seekers claim they can raise student achievement by measuring it more frequently and by constraining everyone in the educational enterprise with more extensive rules and regulations. In its reliance upon control and specification, this reform approach recapitulates the failed school efficiency fad of the 1920s and the similarly discredited "behavioral objectives" movement of the 1970s.

On the other side, feeling a little drowned out, are the curriculum reformers, composed mostly of subject-area experts, classroom teachers, discipline organizations, professional associations, and research centers. This book, while respectful of the need for school performance measures, is unequivocally part of this latter movement for school renewal through curriculum reform. Our vision of school improvement relies not on new rules and controls, but on improved instruction. We believe that schools are clinging to inefficient, ineffective teaching practices that urgently need to be replaced. We reject the idea that doing the same things harder, longer, and stronger will materially improve education. We repudiate the assumption

that achievement can be elevated by giving students more and more tests, no matter how “rigorous.” As one of our agriculturally savvy friends recently commented: “You can weigh the pig as many times as you want; the scale won’t fatten him up.”

In our lowest moments (happily, not too frequent or extended), we tend to look at the two standards movements in this way. The original curriculum standards projects were developing what were called “opportunity-to-learn” standards, statements about what kind of experiences, teaching, materials, and supports kids need in order to learn. They were basically asking the question, What can we do for kids? But the now-ascendant accountability movement mainly asks, What can kids do for us? How can American school children generate standardized tests scores that enrich test makers and publishers, provide evidence for privatization efforts, undermine left-leaning teachers unions, and help tough-sounding legislators get reelected? The accountability gang stays focused on measuring the purported outcomes of education, not on providing the inputs (like funding, smaller class sizes, better materials, and more teacher training) that might actually *improve* the results.

If we sound especially concerned with issues of equity and opportunity to learn, that’s because these issues have tripped up almost all previous reform movements in America. Reform means nothing unless *all* students have genuine access to the kind of instruction that makes reaching high standards possible. We can’t help commenting that the suburban town where we happen to be writing today spends over \$15,000 per year on each of its high school students. Cross Howard Street into Chicago and the expenditure drops to \$7,700. Like it or not, genuine school reform requires changes in accounting, not just accountability.

WELCOME TO BEST PRACTICE

Undoubtedly this debate, along with its acrimony and political chicanery, will continue long into the future. But the curriculum standards movement, and the historic documents it has generated, will continue to guide well-informed schools and teachers, especially in this impulsive and politicized era. While transient state standards and tests, like most politically driven reforms, tend to be volatile, inconstant, and self-contradictory, the curriculum and teaching standards developed inside the teaching profession by people who know content and understand kids will prevail over decades. Even now, most of the country’s truly high-achieving schools, including some of our

most costly and elite private schools, chart their course by the Best Practice map every day.

So this book is about the really big ideas in education, the ones with depth and staying power. You'll soon be visiting classrooms and schools where these enduring ideas are honored and their distinctive activities are enacted. And while *Best Practice* deals mostly in facts, it also has a strong, unabashed, and partisan vision: we believe (and we hope we are about to prove) that progressive educational principles can and should govern classroom practice in American schools. While some people belittle the past cycles of progressive innovation during the 1930s and 1960s as transient fads, this book shows how the current wave of curriculum-based reform connects and culminates those past eras, and offers hope of creating the strongest and most enduring school reforms this country has ever seen.



Chapter 1

Renewing Our Schools:

The Progressive Consensus

This is both an exciting and disturbing time for America's schools. For twenty years we have been enduring the most intense period of educational reform this country has ever experienced. Nearly everyone has gotten into the act: politicians, parents, teachers, taxpayers, teacher-educators, social critics, journalists, and researchers—all of them passionately involved in school renewal. Education-oriented cover stories, blue-ribbon commissions, government reports, exposés, recommendations, talk shows, documentaries, conferences, jokes, gossip, and legislation abound. Indeed, we are writing this book during the reign of yet another “Education President,” in a state with a self-declared “Education Governor,” and in Chicago, a city famed for its drastic and occasionally effective school reforms. For the moment, at least, education is the issue of the day.

This universal worry about the health of our public schools was deliciously portrayed in a *New Yorker* cartoon. A horrifying, ten-story-tall reptile, presumably from outer space, rampages through a downtown square as crowds of citizens run for their life in every direction. One man at the head of the fleeing crowd turns to a fellow runner and comments: “Just when city-wide reading scores were edging up!”

While all the heartfelt public concern about education is certainly useful, very little of this sudden interest has been admiring, pleasant, or even civil. Our national reappraisal of education began with widespread anger about urban dropout rates, worry about low test scores, and fears about the perceived slippage in American workers' global competitiveness. These worries are constantly stirred by a drumbeat of downbeat headlines, such as this morning's offering: “U.S. Slips in Education Ratings: America Falls Behind in Number of Those Who Finish High School” (Feller 2004). Not

surprisingly, much school reform energy has been spent on blaming and finger-pointing: responsibility for our nation's educational disappointments has been enthusiastically and variously apportioned among TV, video games, single-parent families, ill-trained teachers, urban gangs, bad textbooks, sexual permissiveness, drugs, schools of education, and dozens of other causes.

Undeniably, the current debate about schools has included plenty of non-constructive turmoil and rancor. Still, on balance, those of us who work in schools must welcome the scrutiny and even the fractiousness. After all, it is a rare and overdue moment when education leaps to the top of the national agenda—and it is during unstable periods like this one that true change often begins. So no matter what misgivings we might have about the current era of school reform, one thing is sure: today, millions of Americans are thinking hard and talking urgently about their schools. And that is welcome.

WHAT ABOUT LEARNING AND TEACHING?

One topic is too often missing from this loud, ongoing conversation: *what* shall we teach and *how*? At first, it seems unlikely that amid all this furor the substance of education could somehow be overlooked, but the record of the reform era so far sadly bears this out. Except for the national curriculum standards documents we'll soon be describing, most public discourse has concerned the organizational features of schooling and "accountability" for its outcomes, rather than its content and methodology. From the trendsetting *A Nation at Risk* onward (National Commission on Excellence in Education 1985), many reports, commission papers, books, and state and local reform efforts have focused on the logistics of schooling, rather than its content and process. The central concerns have been the length of the school day and year, the credentials and pay of teachers, the roles and duties of principals, the financing of schools and school reform, forging connections to the worlds of work and higher education, articulating educational policy with national defense, and, above all, the testing and measurement of school "products." Indeed, the federal government's current No Child Left Behind program challenges *nothing* in traditional curriculum or pedagogy. School-as-usual is just fine with NCLB, which promises only one direct governmental action in the name of educational renewal: more standardized tests for students, teachers, and schools, followed by more systematic labeling and punishing of the "failures."

As we have argued in the Preface, there are now two largely contradictory school reform movements in the United States, one located mainly inside the education profession and another pressing from outside it. The inside group is the curriculum standards movement, composed of subject-matter experts, educational researchers, professional associations, and classroom teachers who believe the key to school improvement lies in more authentic curriculum and revamped teaching methods. The outside group, now holding center stage, is usually called the accountability standards movement. This determined coalition of politicians from both parties, state and federal legislators, state education departments, testing companies, and conservative think tanks, along with some educators, believes that schools will improve through tighter controls, more regulation, and frequent high-stakes standardized tests with tough consequences.

This latter position is sometimes hard for parents and taxpayers to understand. How are kids supposed to pass all those new tests if something isn't done to make them smarter, more ready, more educated, *before* the test booklets hit the desk? How can you ignore subject matter and teaching practices in any serious conversation about school improvement? Writing in *Educational Leadership* more than a decade ago, our colleague James Beane addressed this peculiar imbalance in contemporary school reform debates, and what he argued still holds true: "It seems that no matter how radical restructuring talk may otherwise be, it almost never touches upon the curriculum itself. Much of what passes for restructuring is, in a sense, new bottles for old wine that has not gotten better with age. How is it that we can claim to speak of school reform without addressing the centerpiece of schools, the curriculum?" (1991).

This gap doesn't seem to bother the accountability-oriented reformers. With the exception of a few commercial purveyors of "cultural literacy" (Bennett 1993; Hirsch 1996; Ravitch 2003), surprisingly few of the accountability folks have paid serious attention to changing the *content* of schooling. If our schools indeed have failed as utterly as so many blue-ribbon commissions claim, then immediate changes in the curriculum would seem advisable. To be sure, many states have compiled compendia of mandatory subject matter, not just in weighty guidebooks, but on trillion-gigabyte websites too. But the preponderance of this specified curriculum is 1950s-vintage subject matter—the same old textbook-driven, cover-everything string of factoids, digitalized for schools of the new millennium. The only thing new is the delivery system.

Similarly, the methods of teaching have been thoroughly ignored in the current debate. With notable (and valuable) exceptions like George Wood, TheodoreSizer, Alfie Kohn, and Deborah Meier, the people who write about school reform rarely focus systematically on teaching *processes*—the nature of the interactions between kids and teachers. Again, if our educational system truly has collapsed, then the careful critique and revision of instructional methods would seem an urgent priority. We should be figuring out how to rearrange the basic ingredients of school—time and space and materials and ideas and people—to maximize student learning. Instead, the topic of teaching methods is not just ignored, it is often explicitly ridiculed by the accountability reformers as a time-wasting distraction best left to the pea-brained teacher-educators in their despised colleges of education. This is not professional paranoia talking: G. Reid Lyon, one of our top-ranking federal education officials, recently exclaimed: “If there was one piece of legislation I would pass it would be to blow up the colleges of education” (2002).

Sometimes the accountability reformers will even claim that progressive teaching methods have *already* come to dominate American classrooms—and ruined them. But previous innovations like whole language, open classroom, or integrated curriculum, though much debated, have never been widely or faithfully implemented. Even at the height of such movements, the vast majority of classrooms have carried on unaffected with lecture-test instruction. Indeed, over the last century of astonishing technological and cultural change, our educational institutions have arguably changed *less* in form and function than any other social structure. Indeed, if a person from the 19th century were suddenly transported ahead to their present-day home town, the only recognizable and familiar institution would probably be the old public school—even if it were located in a new building.

So, after nearly a generation of “reform” focused on everything but subject matter and methodology, students are still sitting in pretty much the same classrooms with the same teachers, divided into the same instructional groups, doing the same activities, working through the same kinds of textbooks and worksheets, and getting pretty much the same scores on the many new standardized tests that are the only tangible legacy of all the hand-wringing and exhortation. In a backhanded and ironic way, the accountability standards movement actually has ended up *endorsing* old modes of schooling. These reformers have never really questioned the day-to-day process and content of American education; instead, they simply assume that

if the same activities are conducted within an enhanced framework—with more time, more resolve, more tests—then student achievement and outcomes will improve. In this version of reform, you simply do the same things harder, longer, and stronger.

Now, this can be a perfectly fine approach if what you already are doing works well and merely requires intensification. Unfortunately, we are coming to understand that the basic things we've done in the past in American schools—what we teach and how—*don't* work: they don't empower kids, don't nurture literacy, don't produce efficient workers, don't raise responsible citizens, don't create a functional democracy. If we really want to change student achievement in American schools, we must act directly on teaching and learning. More of the same is not the answer.

REAL REFORM

While legislatures, blue-ribbon panels, and media sages have designed tests and tinkered with the logistics of education, the other, quieter school reform movement has steadily continued working. Our national curriculum research centers, subject-matter professional associations, capable researchers, and thousands of on-the-line classroom teachers have been struggling to clearly define “best educational practice” in each teaching field. These groups and individuals share a curriculum-driven view of education: they assume that if American schools are to be genuinely reformed, we must begin with a solid definition of the content of the curriculum and the classroom activities through which students may most effectively engage that content. They do not see the shortcomings of American schools as mainly logistical and administrative, but rather a failure of what we teach and how.

Our long-running school reform debate, even though it hasn't concentrated enough on instruction and curriculum, has nevertheless prodded further work in these areas. All the people in the curriculum reform movement—teachers, instructional researchers, professional associations, subject-area leaders—have been rethinking the substance, content, processes, methods, and dynamics of schooling. As a result, in virtually every school subject we now have summary reports, meta-analyses of instructional research, accounts from exemplary classrooms, and landmark professional recommendations. Some of these reports were produced with funding from the U.S. Department of Education; others were independent and self-

financed. Taken together, this family of authoritative documents provides a strong consensus definition of Best Practice, state-of-the-art teaching in every critical field.

One might expect that when experts and practitioners from such disparate fields as art, science, mathematics, reading, writing, and social science sit down to define their own field's Best Practice, the results would reflect very different visions of the ideal classroom, contradictory ways of organizing subject matter, and divergent models of what good teachers do. But in fact, such polarities do *not* characterize these reports. Whether the recommendations come from the National Council of Teachers of Mathematics (NCTM), the National Board for Professional Teaching Standards (NBPTS), the National Writing Project (NWP), the National Council for the Social Studies, the American Association for the Advancement of Science (AAAS), the National Council of Teachers of English (NCTE), the National Association for the Education of Young Children (NAEYC), or the International Reading Association (IRA), the fundamental insights into teaching and learning are remarkably congruent. Indeed, on many key issues, the recommendations from these diverse organizations are unanimous. Following on pages 8–9 is a list of these common conclusions—features that begin to define a coherent paradigm of learning and teaching across the whole curriculum.

The latent agreement on these principles is so strong in the various subject fields that it seems fair to call it an *unrecognized consensus*. Although school people are often portrayed as lost and fragmented, the fact is that a remarkably consistent, harmonious vision of “best educational practice” already exists. The coherence of this vision, the remarkable overlap across fields, is quite striking, though even some people in the educational system haven't yet grasped its significance and potential transforming power.

Admittedly, this emerging consensus is not perfectly symmetrical across the different school subjects; some fields are ahead of others. Reading and writing are probably the most advanced in implementing Best Practice instruction, although they were among the slowest to publish official standards. Approaches like Reading/Writing Workshop, Process Writing, Writing Across the Curriculum, Reading as Thinking, and Strategic Reading, which have been solidly in place for years, have been leading the way for practitioners and researchers alike. Although no comparably broad instructional movements yet exist in mathematics, math leaders have made a tremendous contribution with the series of NCTM standards documents published since 1987. These guidelines have shown other fields how learning

goals for children can be described in Best Practice terms—progressive, developmentally appropriate, research-based, and eminently teachable. In contrast, while science educators have a decades-long tradition of supporting progressive, hands-on, student-centered instruction, they’ve had less success with implementation in schools. This relative lack of impact undoubtedly reflects the low priority given to science at all levels of American education: science often gets pushed to the bottom of the curricular agenda, while worries about reading, writing, and math gobble up time, attention, funding, and the energy for staff development.

The social sciences have been especially uneven in embracing progressive practices and disseminating them throughout the profession. At first, this seems surprising, because subjects like history, civics, and geography appear to cry out for collaborative, experiential, student-centered, cognitive approaches—key structures in the emerging Best Practice paradigm. But, as we discuss further in Chapter 6, social studies education has been tangled up in its political baggage. Because this is the one school subject with the explicit duty to inculcate civic values and transmit “necessary” cultural information, it becomes a battleground on which partisans take nonnegotiable stands. The first draft of the national history standards, by some accounts a balanced but warts-and-all version of U.S. and world history, was voted down by the U.S. Senate after right-wing commentators waged a furious media campaign.

For several years, the vociferous and virulent attacks of high-profile critics like E. D. Hirsch and William Bennett intimidated social studies teachers. For some reason, educators rarely pointed out the obvious conflict of interest: Bennett and Hirsch, far from being judicious observers of the educational scene, are both tireless commercial vendors, marketing “cultural literacy” products (e.g., *What Your Second Grader Needs to Know*, *The Book of Virtues*) to American schools and parents. Finally, after years on the defensive, the National Council for the Social Studies in 1994 issued a set of documents that, along with the revised history and geography standards, staked out a solid progressive position for social science education, despite the continuing fulminations of pundits.

PRINCIPLES OF BEST PRACTICE LEARNING

As the More/Less list on pages 8–9 suggests, there is more afoot here than the congruence of teaching recommendations from traditionally separate fields



Common Recommendations of National Curriculum Reports

- LESS whole-class, teacher-directed instruction (e.g., lecturing)
- LESS student passivity: sitting, listening, receiving, and absorbing information
- LESS presentational, one-way transmission of information from teacher to student
- LESS prizing and rewarding of silence in the classroom
- LESS classroom time devoted to fill-in-the-blank worksheets, dittos, workbooks, and other “seatwork”
- LESS student time spent reading textbooks and basal readers
- LESS attempts by teachers to thinly “cover” large amounts of material in every subject area
- LESS rote memorization of facts and details
- LESS emphasis on the competition and grades in school
- LESS tracking or leveling students into “ability groups”
- LESS use of pull-out special programs
- LESS use of and reliance on standardized tests

- MORE experiential, inductive, hands-on learning
- MORE active learning, with all the attendant noise and movement of students doing, talking, and collaborating
- MORE diverse roles for teachers, including coaching, demonstrating, and modeling
- MORE emphasis on higher-order thinking; learning a field’s key concepts and principles
- MORE deep study of a smaller number of topics, so that students internalize the field’s way of inquiry
- MORE reading of real texts: whole books, primary sources, and nonfiction materials

- MORE responsibility transferred to students for their work: goal setting, record keeping, monitoring, sharing, exhibiting, and evaluating
- MORE choice for students (e.g., choosing their own books, writing topics, team partners, and research projects)
- MORE enacting and modeling of the principles of democracy in school
- MORE attention to affective needs and varying cognitive styles of individual students
- MORE cooperative, collaborative activity; developing the classroom as an interdependent community
- MORE heterogeneous classrooms where individual needs are met through individualized activities, not segregation of bodies
- MORE delivery of special help to students in regular classrooms
- MORE varied and cooperative roles for teachers, parents, and administrators
- MORE reliance on descriptive evaluations of student growth, including observational/anecdotal records, conference notes, and performance assessment rubrics

SOURCES: American Association for the Advancement of Science 1989, 1997, 1998, 2001; Americans for the Arts 2005; Anderson et al. 1985; Bybee et al. 1989, 1991; California Arts Council 2001; Center for Civic Education 1994; Consortium of National Arts Organizations 1994; Crafton 1996; Critical Links 2002; Dunn and Vigilante 2000; Farstrup and Samuels 2002; Fiske 1998; Geography Education Standards Project 1994; Harste 1989; Hiebert et al. 2003; Hillocks 1986; International Reading Association and National Council of Teachers of English 1996; Joint Committee on National Health Education Standards 1995; National Association for the Education of Young Children 2002; National Board for Professional Teaching Standards 2005; National Center on Education and the Economy 1995; National Center for History in the Schools 1994a, 1994b; National Commission on Reading; National Council for the Social Studies 1994; National Council of Teachers of Mathematics 1989, 1991, 1995, 2000; National Reading Panel 2000; National Research Council 1996, 2000; National Science Teachers Association 1996, 2000; President's Committee on the Arts and the Humanities and Arts Education Partnership 1999; National Staff Development Council 2001; Routman 2003; Saunders and Gilliard 1995; Sierra-Perry 1996; Smagorinsky 1996; U.S. Department of Labor SCANS Report; Wilhelm 1996.

of the American school curriculum. A more general, progressive educational paradigm is emerging across content boundaries and grade levels. This coherent philosophy and spirit is reaching across the curriculum and up through the grades. Whether it is called Best Practice, integrated learning, interdisciplinary studies, or authentic instruction, or some other name or no name at all, this movement is broad and deep and enduring. It is strongly backed by educational research, draws on sound learning theory, and, under other names, has been tested and refined over many years.

What is the nature of this new/old curriculum? What assumptions and theories about learning inform this approach? What is the underlying educational philosophy of this reemergent paradigm? If we study the more/less list systematically, we can identify thirteen interlocking principles, assumptions, or theories that characterize this model of education. These principles are deeply interrelated, each influencing the others. And the list of principles, as you'll see, can be grouped into three main clusters. The first five elements address various aspects of student-centered teaching and learning.

STUDENT-CENTERED: The best starting point for schooling is young people's real interests; all across the curriculum, investigating students' own questions should always take precedence over studying arbitrarily and distantly selected "content."

Experiential: Active, hands-on, concrete experience is the most powerful and natural form of learning. Students should be immersed in the most direct possible experience of the content of every subject.

Holistic: Children learn best when they encounter whole ideas, events, and materials in purposeful contexts, not by studying subparts isolated from actual use.

Authentic: Real, rich, complex ideas and materials are at the heart of the curriculum. Lessons or textbooks that water down, control, or oversimplify content ultimately disempower students.

Challenging: Students learn best when faced with genuine challenges, choices, and responsibility in their own learning.

The next five principles draw our attention to cognitive and developmental aspects of teaching and learning.

COGNITIVE: The most powerful learning comes when children develop true understanding of concepts through higher-order thinking associated with various fields of inquiry and through self-monitoring of their thinking.

Developmental: Children grow through a series of definable but not rigid stages, and schooling should fit its activities to the developmental level of students.

Constructivist: Children do not just receive content; in a very real sense, they recreate and reinvent every cognitive system they encounter, including language, literacy, and mathematics.

Expressive: To fully engage ideas, construct meaning, and remember information, students must regularly employ the whole range of communicative media—speech, writing, drawing, poetry, dance, drama, music, movement, and visual arts.

Reflective: Balancing the immersion in experience must be opportunities for learners to reflect, debrief, and abstract from their experiences what they have felt and thought and learned.

The final three principles remind us to attend to the social and interpersonal aspects of teaching and learning in schools.

SOCIAL: Learning is always socially constructed and often interactive; teachers need to create classroom interactions that “scaffold” learning.

Collaborative: Cooperative learning activities tap the social power of learning better than competitive and individualistic approaches.

Democratic: The classroom is a model community; students learn what they live as citizens of the school.

We can represent these three clusters of principles graphically, as shown in Figure 1.1.

The remainder of this book, as we discuss each subject in the school curriculum, spells out what these key principles really mean in practice. However, to explain why these ideas are so important, we’ll elaborate briefly on them now.

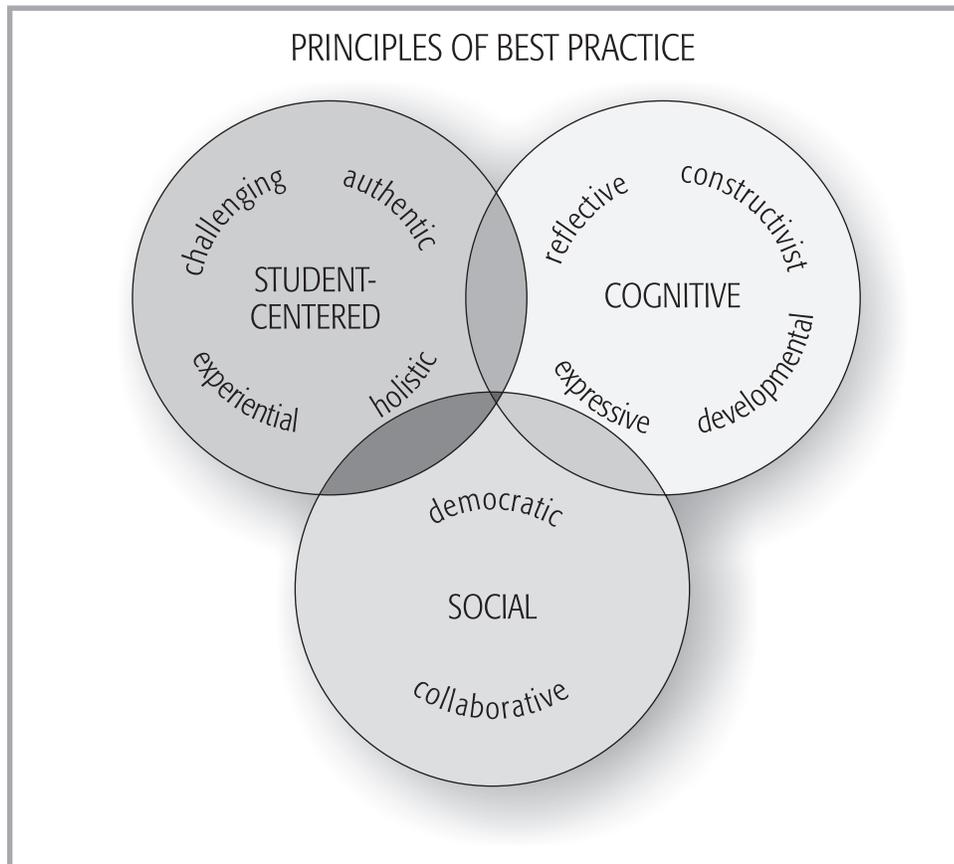


Figure 1.1: Principles of Best Practice

Schooling should be **STUDENT-CENTERED**, taking its cues from young people’s interests, concerns, and questions. Making school student-centered involves building on the natural curiosity children bring with them and asking kids what they want to learn. Teachers help students list their own questions, puzzles, and goals, and then structure for them widening circles of experience and investigation of those topics. Teachers infuse into such kid-driven curricula all the skills, knowledge, and concepts that society mandates—or that the state curriculum guide requires—though always in original sequences and combinations. But student-centered schooling does not mean passive teachers who respond only to students’ explicit cues. Teachers also draw on their deep understanding of children’s developmental needs and enthusiasms to design experiences that lead students into areas they

might not choose, but that they will enjoy and engage in deeply. Teachers also bring their own interests into the classroom to share, at an age-appropriate level, demonstrating how a learner gets involved with ideas. Thus, student-centered education begins by cordially inviting children's whole, real lives into the classroom; it solicits and listens to their questions; and it provides a balance between activities that follow children's lead and ones that lead children.

As often as possible, school should stress learning that is EXPERIENTIAL. Children learn most powerfully from *doing*, not just hearing about, any subject. This simple psychological fact has different implications in different subjects. In writing and reading, it means that students grow more by composing and reading whole, real texts, rather than doing worksheets and exercises. With mathematics, it means working with objects—sorting, counting, and building patterns of number and shape—and carrying out real-world projects that involve collecting data, estimating, calculating, drawing conclusions, and making decisions. In science, it means conducting experiments and taking field trips to investigate natural settings, pollution problems, and labs at nearby factories, universities, or hospitals. For social studies, students can conduct opinion surveys, prepare group reports that teach the rest of the class, and role-play famous events, conflicts, and political debates. In all school subjects, the key is to help students think more deeply, to discover the detailed implications of ideas through direct or simulated immersion in them.

Learning in all subjects needs to be HOLISTIC. In the traditional American curriculum, information and ideas are presented to children in small “building blocks.” While the teacher may find these subparts meaningful and may know they add up to an eventual understanding of a subject, their purpose and significance aren't always apparent to children. This part-to-whole approach undercuts motivation for learning because children don't perceive why they are doing the work. It also deprives children of an essential condition for learning—encountering material in its full, lifelike context. When the “big picture” is put off until later, later often never comes. We know that children do, in fact, need to acquire skills and abilities such as spelling and multiplying and evaluating good evidence for written arguments. But holistic learning means that children gain these abilities most effectively by going from whole-to-part, when kids read whole books, write whole stories, and



Chapter 4

Best Practice in Mathematics

THE WAY IT USED TO BE

We often ask adults to write their math autobiographies, and their stories would make a grown man cry. They struggled through a labyrinth of incomprehensible symbols and rules, memorizing facts and procedures. They remember their panic when called upon to go to the chalkboard to compute $2\frac{1}{2}$ divided by $\frac{5}{12}$. “Ours is not to reason why; we just invert and multiply.” Many of these adults are now parents, and they not-so-subtly send a message to their children: “Math is hard. I never could understand it. Gee whiz, I can’t even balance my checkbook.”

Is mathematics so inherently difficult that only a few who are “wired” for math can understand it? Unfortunately, most people in the United States would say yes. This erroneous view of mathematics has been prevalent for decades. Many come to believe that they are incapable of doing math. As they progress through the grades, fewer and fewer students understand and enjoy math, leaving only a handful to continue with capability and confidence. Most high school students take the minimum number of math classes needed to graduate. By college, only a small percentage of our nation’s students elect to major in mathematics. Others take only the minimum courses required, despite the fact that many careers depend upon mathematical knowledge.

It does not have to be this way. We know more than ever before about human cognition and how to help students understand mathematics. Here is how one middle school teacher, Katie George, used “Chocolate Algebra,” an activity from Arthur’s course on teaching algebra, and implemented it in her classroom at Daniel Wright Junior High School in Lincolnshire, Illinois.

TEACHING MATHEMATICS A BETTER WAY: CHOCOLATE ALGEBRA

Armed with a giant bar of chocolate and a king-sized box of Tootsie Rolls, I prepared my initial attack on linear equations with my seventh-grade students. My objective for the day was simple: introduce linear relationships, one of the cornerstones for beginning algebra students. From the several times I'd done this activity, I was keenly aware that Chocolate Algebra hinges on careful pacing and precise questioning. I planned two 44-minute class periods for this activity.

I began by posing a problem to my class: "If you have \$10 to spend on \$2 Hershey Bars and \$1 Tootsie Rolls, how many ways can you spend your money without receiving change? All chocolate, no change—tax included." I had determined in advance the items to purchase and the dollar amounts to spend so that the tables and graphs would reveal patterns readily. Bringing in props such as large candy bars was very motivating for the students and provided concrete representations.

The students quickly began generating solutions. As expected, most randomly jotted down any combination that popped into their minds. As they shared solutions, it became apparent that we needed an organizational system. With scheming intent, I suggested they each make a simple two-column table (or T-chart) to keep the combinations in order. We decided as a class to label the left-hand column "Number of Hershey Bars" and the right-hand column "Number of Tootsie Rolls."

The combinations elicited from the class were not arranged in any particular order. I asked them, "Did you find all the possible combinations?" To make it easier to answer, we agreed to purchase the most \$2 Hershey Bars that we could as a place to start ("the most of the bigger item") and decrease the number of Hershey Bars one at a time. The first row of our table showed that 5 Hershey Bars and 0 Tootsie Rolls were purchased. The second row had 4 Hershey Bars and 2 Tootsie Rolls. The class quickly saw patterns and the table was complete in a matter of minutes.

We spent a lot of time talking about patterns in the tables. By using a different color pen to highlight one pattern, I asked the class to explain to me how the numbers changed in the table. "The left side goes down by one and the right side goes up by two," one student exclaimed. "Why?" I asked. Another student asked, "Will the left side always go down and the right side always go up?" Yet a different student asked, "Will the numbers at the

top always make the pattern?” I countered, “Where does the pattern come from?” Many students volunteered that because the Hershey Bar was twice as expensive, there would be a 2:1 relationship. “Oh, the Hershey Bar is exchanged for two Tootsie Rolls!” one student said as a big light bulb appeared over her head. As I expected, the vast majority of the students now understood the tables and could recognize the patterns.

To extend the concept, I had them try to buy \$1 Tootsie Rolls and \$5 Toblerone Bars with \$27 dollars and, finally, \$5 Toblerones and \$2 Hershey Bars with \$37. Again, they made tables and discussed the patterns they saw. These students had worked with equations having one variable but this would be their first classroom experience with two, so I wanted to tread very carefully. I ended by asking, “Is there another way to represent this situation?”

To start the second day, we pulled out our tables again and reviewed the situation from the previous class. Out to the side of the table on the board, I wrote each solution as a coordinate point with parentheses and a comma. “Does this format remind you of anything you have seen before?” I inquired. “Yes, it is for graphing,” several students replied. I spent a couple of minutes reviewing the basics of graphing for those who needed a reminder. “Let’s see what happens if we use our table as a collection of coordinate points and put them on a graph,” I said. They each graphed the points but seemed thoroughly unimpressed. I could see “so what?” written all over their faces.

“Take your pencil and put it on the point $(0, 10)$. Let’s say we want to go from this point to $(1, 8)$, the next point down, but our pencil has to stay on the lines like in a video game. Can someone tell me how to move my pen so that it will be on the point $(1, 8)$?” I prodded. “Move down,” someone called out. “How far should I move?” I responded. “Move down two and over one,” a student directed. Almost instantaneously, most of them realized what was going on. “That’s the pattern in the table! Cool!” As if I had performed a magic trick, my pre-algebra classes delighted in watching the pattern from the table reappear in the graphs. We moved down two and over one until our pencils were on the point $(5, 0)$. “But our table said up two and down one. It is backward,” Jackie whined. “What happens if we go in the other direction? Can we go back to point $(0, 10)$ using a different path?” I inquired, knowing that they were not quite ready for slope but hoping that this would lay a nice foundation for them.

After playing around with the graph and the table for a few minutes, the class had a good initial understanding of the connection between the table

and the graph. In fact, they could see that there was a relationship between the number of Hershey Bars and the number of Tootsie Rolls. The word *cool* was completely overused in my classroom over the course of those two days.

Looking at the tables, I hinted that perhaps we could make an equation from this information. Given the look on their faces, I knew that my suggestion had been a huge leap from a candy-purchasing example to the mysterious world of mathematics. How could we bridge the expanse? “Let’s look at our first table. There is a lot going on here. What numbers are always staying the same?” Without much hesitation, the kids recognized that the price of the candy (\$2 and \$1) and our budget (\$10) always stayed the same. On the board, I wrote down those numbers (\$2 \$1 \$10) with space between them for the symbols and variables that I was hoping they would produce.

“Let’s look at the table again. What is changing? What is different in every row or every situation?” I asked. A bit more hesitation than the first question, but they recognized that the number we were buying was changing. “What can we do to show that a number is changing or that we don’t know what the number will be?” I inquired. “Use a variable,” Sunny said. “X,” Jackie contributed.

“Think about the relationship between the price of the candy, the quantity that we purchased, and our total budget. How can we add variables to the numbers I wrote down to show that the amounts change?” I asked. Most of the students wanted to use H for the number of Hershey Bars and T for the number of Tootsie Rolls.

“Where should we put the H and the T ?” I pushed. The students decided on the variables and their placement to come up with the following equation: $\$2 H + \$1 T = \$10$. “How do we know that this will work? Let’s look back at the table,” I directed. Derek explained that as we made the table we had multiplied the number of Hershey Bars by 2 and the number of Tootsie Rolls by 1 and we had to be certain that these two amounts added up to 10. He explained that we got our equation right from the table.

At the end of the lesson, I asked them to think about what we had done and what they had learned. Many mentioned the use of a table and “the most of the bigger.” Others noticed that we were using variables but not solving for them the way that we had in the past. A few students thought we were just buying candy. A few were not sure how we got our equation. This was an introductory activity, requiring follow-up and extensions. For homework, the kids needed to come up with their own problem with a budget and two items to buy. They should make a table, a graph, and try to write an

equation. Most students delighted in creating their own problem and created a table with ease. Quite a few were able to make a graph to go along with their table, but the biggest challenge was in writing an equation. As this is the most abstract part of the activity, it did not come as a surprise that equation writing was the biggest challenge.

Chocolate Algebra has many, many layers, easily extended or modified; I just change the objects and their costs. It is a fabulous springboard for a unit on linear equations. It can be used in various formats throughout a school year as a way to expand on concepts over time. All my students, regardless of their level, had a revelation at some point.

A LOOK AT THE STANDARDS DOCUMENTS

In 1989 the National Council of Teachers of Mathematics (NCTM) released their landmark document *Curriculum and Evaluation Standards for School Mathematics*. It was followed by *Professional Standards for Teaching Mathematics* (1991), *Assessment Standards for School Mathematics* (1995), and twenty-two addenda booklets that addressed mathematical topics at various grade levels. Taken collectively, the NCTM standards and their related materials offer a significantly broadened view of the nature of mathematics, what it means to know mathematics, how students can learn mathematics, and what kinds of teaching practices best foster this learning.

The influence of the original standards has been substantial. The National Science Foundation (NSF) funded the development of a dozen new curriculum programs that embodied the standards. Most commercial publishers of mathematics textbooks in various ways incorporated these standards in their programs. However, the NCTM standards also stimulated a backlash, dubbed by the media the Math Wars, not unlike the Reading Wars we talked about in Chapter 2. When planning to revise the standards, the NCTM solicited input from a wide range of sources, including many of its most vocal critics. The council published a revision of the standards that integrated the three previous documents into one, *Principles and Standards for School Mathematics* (2000). It did not entirely satisfy the critics.

The 2000 NCTM Standards offer a vision for mathematics based on six major principles

1. **Equity** (maintaining high expectations and support for *all* students).

2. **Curriculum** (articulating coherent, important mathematics across the grades).
3. **Teaching** (challenging and supporting students in building new knowledge).
4. **Learning** (helping students build an understanding of mathematics by actively creating meaning by connecting new knowledge with their prior knowledge).
5. **Assessment** (supporting the learning of important mathematics through formative and summative assessment of what students actually understand).
6. **Technology** (expanding the mathematics that can be taught and enhancing student learning).

In *NCTM 2000* these principles are applied to the **ten standards** for grades K-12. Five **content** standards address the familiar branches of mathematics, and five **process** standards describe the interrelated aspects of cognition that build understanding of concepts.

The ten standards are explained in a global fashion for grades pre-K–12. Then each standard is examined in detail in four grade-level bands (pre-K–2, 3–5, 6–8, and 9–12). **Expectations** of what students should understand, know, and be able to do for each of the five content standards for each grade level are provided in a ten-page appendix. These expectations are a great resource to those developing curriculum frameworks.



Content Standards

Number and Operations

Algebra

Geometry

Measurement

Data Analysis and Probability

Process Standards

Problem Solving

Reasoning and Proof

Communication

Connections

Representations

NCTM 2000 presents additional concepts in the five content standards that were not in the curriculum of prior generations. Also, many concepts are represented and connected in new and exciting ways. The five process standards are drawn from extensive research on human cognition and mathematics. It is our job as teachers to help students learn how to use these processes appropriately to develop the mathematical knowledge described in the content standards.

QUALITIES OF BEST PRACTICE IN TEACHING MATHEMATICS

Teachers should help *all* students understand that mathematics is a dynamic, coherent, interconnected set of ideas. Unfortunately, few teachers, let alone students, have experienced mathematics this way. Most students and adults see mathematics as a collection of unrelated topics, theorems, procedures, and facts. Study after study for the past twenty-five years has found the mathematics curriculum of the United States to be narrowly focused on procedures and facts, not concepts, and highly repetitive, with significant overlap and review from year to year—sometimes covering a topic in the same superficial manner for four or five years in a row.

In order to see mathematics as a coherent whole, one must realize that although numbers and computation are an important part of mathematics, they are only one part. *Mathematics is the science of patterns*. Mathematical concepts describe patterns and relationships. A concept is an abstract idea that explains and organizes information. Mathematicians look for relationships among ideas and try to see patterns in these relationships. Every branch of mathematics (e.g., geometry, probability) has its own patterns. Expert mathematicians use abstract, symbolic notation to describe the patterns they conceive.

The *2000 NCTM Standards* call for the creation of a mathematics curriculum for all students that includes familiar strands but also addresses big ideas, such as patterns, dimension, quantity, uncertainty, shape, and change. These big ideas anchor the important concepts of mathematics as well as terminology, definitions, notation, and skills. Teachers can promote coherence by emphasizing big ideas and helping students see the connections among concepts.



Yes, but . . . is this kind of mathematics teaching really possible?

Sure. Many other countries do mathematics this way. Comparisons of U.S. mathematics curricula with the five top-scoring countries (respectively, Singapore, Korea, Chinese Taipei, Hong Kong, and Japan) in the Third International Mathematics and Science Study (TIMSS) revealed that they focused more on reasoning and understanding concepts, while the U.S. schools stuck more to procedures and facts. The curricula of high-scoring countries had more in-depth study of fewer topics each year (e.g., ten in Japan) compared to the U.S., which had superficial coverage of thirty to thirty-five topics. These high-scoring countries included significant amounts of algebra and geometry in grades six through eight, with the expectation that all students would learn these topics. This expectation contrasted sharply with the finding that 80 percent of U.S. eighth graders study almost exclusively arithmetic topics, with little coverage of algebra and virtually no geometry. The TIMSS authors said the U.S. mathematics and science curricula are “a mile wide and an inch deep” (Schmidt, McKnight, and Raizen 1998, 1).

The goal of teaching mathematics is to help all students understand concepts and use them powerfully. Students should develop true understanding of mathematical concepts and procedures. They must come to see and believe that mathematics makes sense, that it is understandable and useful to them. They can become more confident in their own use of mathematics. Teachers and students must come to recognize that mathematical thinking is part of everyone’s mental ability, and not confined to just a gifted few.

Research in cognitive psychology over the past twenty-five years has consistently shown that understanding increases the ability to learn, remember, and use mathematics (Bransford, Brown, and Cocking 2000). When students learn with understanding, they are able to use their new knowledge flexibly, making connections to new situations. Furthermore, developing a deep, connected understanding of mathematics promotes the learning of computational skills.



Yes, but . . . do you really believe that all or even most students can understand math?

Many more students are capable of learning and understanding more mathematics than previous generations ever thought possible. Conceptual understanding does not come from a teacher *telling* students what a concept is. Concepts are *built* by each person; understanding is created. Students have to explore many examples and talk about what they see and think, as well as hear explanations from the teacher.

In Japan, teachers' primary concern is helping students understand mathematical concepts. The additional time gained by in-depth attention to fewer ideas allows the teachers to help students examine mathematical relationships in depth. The TIMSS research found that in Japan more than half (54 percent) of the problems that students worked on emphasized making connections among many mathematical concepts, versus an anemic 17 percent in the United States. What were American teachers doing? More than two-thirds of their problems emphasized procedural skills. When challenging problems were addressed, the Japanese teachers *required* students to discuss solutions to make connections; *none* of the American teachers in the study did so. In fact, a third of time the teachers *just gave the answer*. It is not surprising to find that the average amount of time spent on a problem was fifteen minutes in Japan and five minutes in the United States (Hiebert et al. 2003).

Teachers in Japan focused on developing new concepts and solving problems that reveal concepts; they spent 60 percent of class time on new content (compared to less than 25 percent by the Americans). Instead of working with new content, the American teachers spent over half the class time on review (versus less than one-fourth of the time by the Japanese). An astonishing 28 percent of U.S. classes were devoted *entirely* to review (versus only 5 percent of Japanese classes). American teachers focused much more heavily on memorizing, although interviews revealed that many American teachers thought they were teaching for understanding. American students were practicing skills while Asian students were thinking. Clearly, the Japanese teachers believed their students could understand, and they did. In contrast, American traditionalists want us to go "back to basics." *We never left.*

Five intertwined processes build mathematical understanding. Teaching for conceptual understanding means helping students build a web of interconnected ideas. Teachers provide experiences for students in which they actively engage in these key processes:

- making connections
- creating representations
- using reasoning and developing proofs
- communicating ideas
- problem solving

Teachers help students *make connections* to their prior mathematical knowledge, between related mathematical concepts, and between concepts and procedures. They help students build bridges between situations or contexts that may appear different but are examples of the same concept. They help students realize the connections between different representations of a problem, which is especially important in moving from concrete to more abstract representations.

A skillful teacher is always juggling examples and explanations. For students to see patterns or to develop true conceptual understanding, they will need many more examples than are provided in the textbook. Presentation of an explanation, no matter how brilliantly worded, will not connect ideas unless students have had ample opportunities to wrestle with examples. An explanation must have something to which it connects.

Making connections requires *reasoning*. Teachers should provide experiences so that students can make and investigate mathematical conjectures, select and use various types of reasoning (inductive pattern finding, deductive logic), and develop and evaluate mathematical arguments and proofs. Reasoning mathematically is essentially a habit; it is developed by use in a variety of contexts. When students believe that mathematics is supposed to make sense, that patterns can be uncovered, and that they can justify the results of their investigations, they are more willing to develop the habit of reasoning.

Problem solving is an excellent vehicle for developing understanding. Traditionally, problem solving has been seen as an application of skills *after* mastery. But the *2000 NCTM Standards* show that problem solving is a means to build mathematical knowledge. Teachers should choose worthwhile mathematical problems or tasks for students to work on. How to solve these problems should not be obvious; students should have to think. The best problems are authentic, challenging, intriguing, mathematically rich,

and perhaps counterintuitive. With help from the teacher to apply and adapt good problem-solving strategies, the students can attack problems and develop understanding. Teachers need to help students develop *metacognition*—being aware of their own problem-solving processes, monitoring their progress, and reflecting on their own thinking.

Teachers need to ensure that students gain experience with a variety of strategies and are able to decide when to use each one. With the most powerful strategies, students *create their own representations*. The common strategies of looking for a pattern and using logical reasoning are overarching and are essential to doing mathematics. Students must be encouraged to look for patterns and to use logical reasoning in *every* problem. But at a more specific level, students should develop capability with five critical strategies that are based on creating representations:

- Discuss the problem in small groups (language representations).
- Use manipulatives (concrete, physical representations and tactile sense).
- Act it out (representations of sequential actions and bodily kinesthetic sense).
- Draw a picture, diagram, or graph (visual, pictorial representations).
- Make a list or table (symbolic representations).

These representations build understanding of the problem (and often find a solution) because in creating them, students are developing different *mental models* of the problem or phenomena. In worthwhile tasks, students may use several of these representations, moving from one to another to figure out more about the problem. Later they might draw on supplementary strategies (e.g., guess and check; work backwards, simplify problem), but these cannot be used effectively unless one understands the problem. As students become more mathematically sophisticated, they are able to use more abstract and symbolic strategies (e.g., use proportional reasoning, apply a formula).

Students often need help from the teacher to move back and forth between representations, seeing how they are related and how each reveals something different. Recall how Katie George asked questions designed to help students see the connections between the actual chocolate items and the numbers in the table, between a row in the table and a point on the

coordinate graph, and between the symbols “(4, 2)” and the situation in real life. Flexibility of translating between representations and realizing the value of each are good indicators of true understanding.

In mathematics, students should be encouraged and helped to *communicate* their ideas by using a full range of language representations—speaking, writing, reading, and listening. Communication and reflection go hand in hand. Even though symbols are used to represent the most abstract aspects of mathematics, the symbols represent ideas that are developed and expressed through language. Oral language—discussing, verbalizing thoughts, “talking mathematics” for most students, most of the time, greatly facilitates their understanding. Of course, teachers must build a safe environment in their classroom where students believe they can freely express their ideas without negative consequences for mistakes.

Math journals provide another opportunity for students to use language to express and justify their reasoning and ideas. They can describe how they solved a problem, why they used a particular approach or strategy, what assumptions they made, and so forth. When they have to explain a mathematics concept in their own words, students have to think and rethink what is really important. With feedback from the teacher, they begin to move from the specifics of each activity to more general and abstract conceptions, expressed more precisely in mathematical language. Eventually, children’s mathematical language, oral and written, becomes a powerful tool for thinking, helping them create *models*—mental maps used to organize their world, solve problems, and explore relationships.

All students should understand and be able to use number concepts, operations, and computational procedures. *NCTM 2000* defines the term *computational fluency* as “having and using efficient and accurate methods for computing” (NCTM 2000, 32). “Developing fluency requires a balance and connection between conceptual understanding and computational proficiency. . . . [S]tudents must become fluent in arithmetic computation—they must have efficient and accurate methods that are supported by an understanding of numbers and operations” (NCTM 2000, 35). Five critically important processes that lead to understanding, proficiency, and fluency need to be developed in many different contexts to gain generalized understanding. They are explained on page 119. When students have many successful experiences using five processes, remembering math facts becomes a simple matter.



Yes, but . . . aren't these ideas controversial?

There is definitely a controversy. Groups of parents, along with a number of mathematicians and scientists, formed a group called Mathematically Correct (MC), and they have spoken out against the NCTM standards. With the help of the Internet, they organized opposition across the United States. In letters to the editor and over the Web, they have posted horror stories of bad math teaching, attributed to the standards. Their website has a hundred “papers”—an amazing collection of half-truths, misconceptions, and rhetoric. The MC folks refer to themselves as traditionalists and criticize NCTM for:

- having students derive math facts and rely on calculators instead of memorizing basic math facts
- having students invent procedures instead of learning traditional algorithms
- focusing on problem solving; cooperative, small groups; and discovery instead of direct instruction
- promoting a curriculum that is “soft and fuzzy” and dumbed-down, with too much fun and games in place of “rigor”

The MC supporters are saying the same things that traditionalists have said for most of this century. From the MC website we read: “‘Understanding’ is a complex, poorly understood process that involves linking multiple stored ‘chunks’ of knowledge. We have no idea how this magical process occurs.”

This quote would be news to the phalanx of cognitive psychologists whose illumination of human “understanding” is described in Bransford, Brown, and Cocking (2000). The MC traditionalists appear to be unaware of the research on cognition showing how concepts are more easily developed, reflected upon, and understood from rich experiences than from facts and procedures that are memorized, but not understood.

This controversy has a long history. “Drill does not develop meaning. Repetition does not lead to understanding,” wrote William Brownell in 1935 (10). “[Algebra] presents mechanical processes and therefore forces the student to rely on memorization rather than understanding. . . . On the whole, the traditional curriculum does not pay much attention to understanding,” wrote mathematician Morris Kline in 1973 (4–5). A group called Mathematically Sane has launched a website to counter the traditionalist critics; visit <http://www.mathematicallysane.com> to see a more comprehensive rebuttal.

RECOMMENDATIONS ON TEACHING MATHEMATICS***Increase******Decrease*****TEACHING PRACTICES**

Use of manipulative materials
 Cooperative group work
 Discussion of mathematics
 Questioning and making conjectures
 Justification of thinking
 Writing about mathematics
 Problem-solving approach to instruction
 Content integration
 Use of calculators and computers
 Being a facilitator of learning
 Assessing learning as an integral part of instruction

TEACHING PRACTICES

Rote practice
 Rote memorization of rules and formulas
 Teaching by telling
 Single answers and single methods to find answers
 Stressing memorization instead of understanding
 Repetitive written practice
 Use of drill worksheets
 Teaching computation out of context
 Reliance on paper and pencil calculations
 Being the dispenser of knowledge
 Testing for grades only

PROBLEM SOLVING

Word problems with a variety of structures and solution paths
 Everyday problems and applications
 Problem-solving strategies (especially representational strategies)
 Open-ended problems and extended problem-solving projects
 Investigating and formulating questions from problem situations

PROBLEM SOLVING

Use of cue words to determine operation to be used

 Practicing problems categorized by type
 Practicing routine, one-step problems

CREATING REPRESENTATIONS

Creating one's own representations that make sense

 Creating multiple representations of the same problem or situation
 Translating between representations of the same problem or situation
 Representations using electronic technology
 Using representations to make the abstract ideas more concrete
 Using representations to build understanding of concepts through reflection
 Sharing representations to communicate ideas

CREATING REPRESENTATIONS

Copying conventional representations without understanding
 Reliance on a few representations

 Premature introduction of highly abstract representations
 Forms of representations as an end product or goal

(continues)

<i>Increase</i>	<i>Decrease</i>
<p>COMMUNICATING MATH IDEAS</p> <p>Discussing mathematics</p> <p>Reading mathematics</p> <p>Writing mathematics</p> <p>Listening to mathematical ideas</p>	<p>COMMUNICATING MATH IDEAS</p> <p>Doing fill-in-the-blank worksheets</p> <p>Answering questions that need only yes or no responses</p> <p>Answering questions that need only numerical responses</p>
<p>REASONING AND PROOF</p> <p>Drawing logical conclusions</p> <p>Justifying answers and solution processes</p> <p>Reasoning inductively and deductively</p>	<p>REASONING AND PROOF</p> <p>Relying on authorities (teacher, answer key)</p>
<p>MAKING CONNECTIONS</p> <p>Connecting mathematics to other subjects and to the real world</p> <p>Connecting topics within mathematics</p> <p>Applying mathematics</p>	<p>MAKING CONNECTIONS</p> <p>Learning isolated topics</p> <p>Developing skills out of context</p>
<p>NUMBERS/OPERATIONS/COMPUTATION</p> <p>Developing number and operation sense</p> <p>Understanding the meaning of key concepts such as place value, fractions, decimals, ratios, proportions, and percents</p> <p>Various estimation strategies</p> <p>Thinking strategies for basic facts</p> <p>Using calculators for complex calculations</p>	<p>NUMBERS/OPERATIONS/COMPUTATION</p> <p>Early use of symbolic notation</p> <p>Memorizing rules and procedures without understanding</p> <p>Complex and tedious paper-and-pencil computations</p>
<p>GEOMETRY/MEASUREMENT</p> <p>Developing spatial sense</p> <p>Actual measuring and exploring the concepts related to units of measure</p> <p>Using geometry in problem solving</p>	<p>GEOMETRY/MEASUREMENT</p> <p>Memorizing facts and relationships</p> <p>Memorizing equivalencies between units of measure</p> <p>Memorizing geometric formulas</p>
<p>STATISTICS/PROBABILITY</p> <p>Collecting and organizing data</p> <p>Using statistical methods to describe, analyze, evaluate, and make decisions</p>	<p>STATISTICS/PROBABILITY</p> <p>Memorizing formulas</p>

(continues)

<i>Increase</i>	<i>Decrease</i>
ALGEBRA Recognizing and describing patterns Identifying and using functional relationships Developing and using tables, graphs, and rules to describe situations Using variables to express relationships	ALGEBRA Manipulating symbols Memorizing procedures
ASSESSMENT Making assessment an integral part of teaching Focusing on a broad range of mathematical tasks and taking a holistic view of mathematics Developing problem situations that require applications of a number of mathematical ideas Using multiple assessment techniques, including written, oral, and demonstration formats	ASSESSMENT Having assessment be simply counting correct answers on tests for the sole purpose of assigning grades Focusing on a large number of specific and isolated skills Using exercises or word problems requiring only one or two skills Using only written tests



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