Edited by
Mark A. Constas • Robert J. Sternberg

Translating Theory and Research Into Educational Practice

Developments in Content Domains, Large-Scale Reform, and Intellectual Capacity

TRANSLATING THEORY AND RESEARCH INTO EDUCATIONAL PRACTICE

DEVELOPMENTS IN CONTENT DOMAINS, LARGE-SCALE REFORM, AND INTELLECTUAL CAPACITY

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Preface

The desire to translate research and theory into practice is shared by many who hope to narrow the gap between the theoretical knowledge and empirical findings of researchers and the practical needs of front-line professionals. Although this has been a longstanding goal in the field of education (see Condliffe-Lagemann, 2000), interest in research-based practice has increased greatly over the past few years. What does it mean for an educational program to be research based? What steps need to be taken by researchers and practitioners to create better connections among theory, research, and educational practice? What challenges might one encounter in the effort to establish such connections? What are some of the common themes found across programs of research that are concerned with translating research into practice? In this volume, focusing on questions such as these, we bring together a collection of well-known researchers who have substantial experience in trying to establish connections between the knowledge produced by the research community and the practices employed in school settings. Authors who have contributed to this volume have spent a considerable amount of energy exploring the practical difficulties, political challenges, and theoretical implications related to the effort to apply theory and findings from research to a diverse range of educational settings.

The book is organized into three principal parts, with each part introduced by a brief commentary that highlights some of the significant points of the chapters contained in each part of the book. In Part I of the book—which includes chapters by Alan Schoenfeld (chap. 1, this volume); Shirley Magnussen and Ann Marie Palincsar (chap. 2, this volume); Jack Fletcher, Barbara Foorman, Carolyn Denton, and Sharon Vaughn (chap. 3, this volume); and Robert Calfee, Roxanne Greitz Miller, Kim Norman, Kathy Wilson, and Guy Trainin (chap. 4, this volume) report on attempts to use educational theory and research to improve student learning and achievement in content domains (e.g., mathematics and science) and in skill areas (e.g., reading). The first chapter in this part, by Schoenfeld, provides insights into the theoretical foundations, political obstacles, and practical complexities he has witnessed in his many years of work in the field of mathematics education. (As a chronicle of approximately 40 years of reform efforts in mathematics education, Schoenfeld examines how issues such as the deprofessionalization of teachers, national and local politics, and an inadequate research development infrastructure have inhibited efforts to translate theory and research into practice.) In the chapter by Magnussen and Palincsar, the authors focus on science education and integrate what is known about scientific practice, learning, and the sociocultural context of education. Magnussen and Palincsar's work is significant because it demonstrates how theory and research might influence practice, and it also illustrates how the knowledge of practice might influence theory. In a third chapter by Fletcher et al., the authors describe their large-scale effort to translate and integrate research and theory related to reading instruction. The description of how research, theory, policy, and legislation can work together or against each other provides readers with interesting insights about the conditions needed to effectively translate research into practice. Fletcher et al. demonstrate how efforts to connect research and practice remain challenging even when the research evidence is clear as is the case for early reading instruction. In the final chapter in this first part of the book (chap. 4, this volume), Calfee et al., describe the challenges and documents the successful strategies have used to promote literacy through selected professional development activities. The chapter by Calfee et al., (chap. 4, this volume) is significant because it raises questions about translation of research and theory into practice by posing a series of challenging questions about how to define and judge the quality of research. By interrogating long-held views about the conceptual, methodological, and empirical foundations of education research, Calfee et al. give a new way to approach the problem of translating research and theory into educational practice.

In Part II of the book, the authors focus on the challenges of large-scale reform. This section includes chapters by James Comer and Edward Joyner (chap. 7, this volume), Robert Slavin (chap. 5, this volume), James Edward Zigler and Matia Finn-Stevenson (chap. 8, this volume), and Christine Finnan and Henry Levin (chap. 6, this volume). Describing their efforts to translate theory and research into practice in the School Development Project, Comer and Joyner illustrate the ways in which principles of human development may be applied to educational settings. Comer and Joyner argue that failures related to attempts to translate theory and research into practice can be remedied if we pay closer attention to research knowledge derived from studies of child and adolescent development. Zigler and Finn-Stevenson describe their work with the School of the 21st Century (21C), a school-based program that has been implemented in approximately 1,300 schools across the country. Different than most educational programs, 21C has focused its reform agenda on the provision of quality child care. By demonstrating important connections between early-childhood care provisions and development in early childhood, Zigler and Finn-Stevenson illustrate the value of drawing upon research and theory outside of the field education. In the chapter by Slavin, he describes the development of Success For All (SFA), a school-improvement program that has its roots in the theory and research on cooperative learning. As both a report on the achievements and an analysis of remaining challenges of SFA, Slavin offers practical advice and theoretical insights about the dynamic interaction of theory, research, and practice. As the final chapter in this second part of book, Finnan and Levin describe the ways in which the Accelerated Schools Project (ASP) has developed and implemented a transformative response to the practical challenges found in schools that serve "disadvantaged" student populations. Over a period of nearly 20 years, ASP has been implemented in more than 1,000 schools across the United States and in a number of school settings outside of the United States. Finnan and Levin use this broad implementation experience to describe their efforts to translate theory and research into practice.

All efforts to enhance learning are based, either implicitly or explicitly, on a theory of how the mind works and on how intellectual skills and abilities may be most effectively developed. Recognizing the foundational importance of theories of intellect, the authors in Part III of this book explore the ways in which different models of intelligence have informed educational practice. In the first chapter in this part, Robert J. Sternberg et al. (chap. 9, this volume) demonstrate how efforts to develop interventions of increasing scale (e.g., from schools to districts to regions) has led their team of investigators to develop and apply the notion of contextual variation to their work on successful intelligence. In this chapter, Sternberg et al. provide empirical data on the effects that educational context has had, and will continue to have, on the implementation of instructional interventions. The chapter by Sternberg et al. is significant because the authors approach the frequently noted but rarely examined notion of educational context as a research construct, a construct that they argue should be subject to focused empirical investigation. In the chapter by Joseph Renzulli (chap. 10, this volume), he documents his work in the area of gifted education, which combines an analysis of theoretical developments and empirical analysis of research on giftedness and creativity with a description of the professional challenges he has encountered in his effort to close the gap between research and practice.

Renzulli's chapter is significant because he raises important issues about the way in which attempts to translate theory and research into practice are of practical concern. Renzulli also shows how theoretical developments are mediated by the dynamics of political context(s) (e.g., within schools and school districts, within states, and within the research community itself). In the chapter by Mindy Kornhaber and Howard Gardner (chap. 11, this volume), the authors describe a scenario in which the theoretical propositions that form the basis of multiple intelligences (MI) have been implemented without formal organizational supports and outside of the ambitions of the researchers themselves. Kornhaber and Gardner provide an analysis that describes the features of MI that may have led to this phenomenon of self-implementation and offer solutions to the problem of implementation variation. Chapter 11 is significant because Kornhaber and Gardner describe a relatively rare phenomenon, a self-implementing theory, and provide an analysis that is instructive for others who are interested in translating research and theory into educational practice.

Understanding how to build productive connections between research and practice remains a problem for the field of education. *Translating Theory and Research Into Educational Practice* offers a richly detailed account of the challenges encountered and the strategies applied in relation to this problem. Many of the authors from all three parts of the book have committed between 10 and 40 years to narrowing the gap between research and practice. Viewed as a collective effort to translate theory and research into educational practice, the interventions and programs the authors describe across the volume represent nearly 200 years of work. As a compendium of successful strategies, we believe this book may help others identify ways to make their own research more useful to practice communities. As an analysis of persistent, seemingly intractable problems encountered when attempting to connect educational theory and research to the everyday work of teachers in classrooms and schools, the authors in this book demonstrate areas in which additional work is needed. The description of successful strategies and the analysis of seemingly intractable problems the authors provide throughout the book will hopefully spur the interest of researchers who hope to understand how the research community may better respond to the needs of educational professionals.

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I

TRANSLATION OF RESEARCH AND THEORY IN CONTENT AREAS AND SKILL DOMAINS

Commentary

Mark A. Constas and Robert J. Sternberg

The need to translate educational theory and research into practice in content and skill areas has existed for generations. The importance of developing a coherent, effective response to this need has increased significantly over the past few years, as national indicators (e.g., National Center for Educational Statistics, 2003) and international comparisons (e.g., Gonzales, Guzman, & Jocelyn, 2004) have revealed less than ideal outcomes. In the four chapters in this first part of the book, the authors describe comprehensive programs of research in science education, mathematics education, and reading. In the first chapter, Schoenfeld, (chap. 1, this volume) helps describe the challenges of translating research and theory into practice in the field of mathematics education. Schoenfeld's analysis of the tensions between research and practice brings into sharp focus the intersection, and seeming inseparability, of theoretical perspectives and political reactions related to mathematics education. In the chapter by Magnusson and Palincsar (chap. 2, this volume), the authors offer insights about how a multidisciplinary framework related to guided instruction in science has been used to support their attempts to translate theory and research into practice. One of the driving forces behind the work of Magnusson and Palincsar is a concern for building better, more authentic connections between how children are taught science and how scientists themselves engage in the practice of science. Focusing on reading, in the chapter by Fletcher, Foorman, Denton, and Vaughn (chap. 3, this volume), the authors describe the difficulties of translating theory and research into practice even when the foundation of knowledge is fairly well established. Fletcher et al.'s chapter is important because they examine the ways in which theory, research, policy, and legislation exert a combined effect on attempts to bring about meaningful change in instruction. In the final chapter, Calfee, Miller, Norman, Wilson, and Trainin (chap. 4, this volume) describe the demands of trying to influence practice in the area of literacy, in support of basic reading and in support of reading and writing in science. Chapter 4 is significant because Calfee et al. not only offer insights about how to think about education for literacy but also raise questions about the way in which the field of educational research is structured as a scientific enterprise.

As a collection of chapters focused on the investigation of content and skill domains in education, the work of Fletcher et al. (chap. 3, this volume) and of Schoenfeld, Calfee et al., and Magnusson and Palincsar (chaps. 1, 4, and 2, respectively, this volume) introduces provocative questions and offers sound practical advice about how researchers may more effectively engage with and solve problems of practice. The authors in this part of the book explore new ways to conceive of studies and new ways to develop implementation strategies as we seek to translate theory and research into practice in content and skill domains of mathematics, science, and reading.

MATHEMATICS EDUCATION AT THE CROSSROADS OF THEORY AND POLITICS

In Schoenfeld's chapter (chap. 1, this volume), he provides a historical description of the achievements and persistent challenges for the field of mathematics education as it seeks to translate educational theory and research into practice. Beginning with the surge of interest in mathematics and science education in the Sputnik in the 1960s, Schoenfeld shows how varying conceptions of core knowledge, heuristic understanding, and metacognition have influenced the field of mathematics education. Portrayed as a series of "crisis-response" cycles, the field of mathematics education has been the subject of active debate among policymakers, practitioners, and researchers. Schoenfield describes how various school-reform efforts and content standards have shaped instructional practice. Like many content domains, mathematics has been the subject of heated political debate. As Schoenfeld demonstrates, educational research and theory are just two of many forces that act on the practice of mathematics education. Schoenfeld's analysis of the standards-based curriculum that followed the National Council of Teachers of Mathematics (NCTM) standards illustrates both the successes and remaining challenges in the field of mathematics education. A valuable feature of Schoenfeld's chapter is that he connects his analysis of theoretical issues to a broader set of political transitions related to shifting funding priorities and political transitions at the national level. As Schoenfeld (chap. 1, this volume) argues, somewhat discouragingly (but realistically!), “education is still much more hostage to politics than it is to incremental improvement through research-based means” (p. xx). Schoenfeld cites a range of structural features, institutional practices, and professional pressures that mitigate against the possibility of creating well-established sustained effort to more effectively and more consistently translate educational theory and research into practice. With reference to structural issues, Schoenfeld argues that an “engineering infrastructure” is needed for the field of education, an infrastructure that will support research development work in education. What is perhaps most distinctive of Schoenfeld’s analysis is that he provides a comprehensive description and insightful analysis of the disciplinary developments, political forces, and practical constraints that have the shaped the field of mathematics education over the past 40 years. Schoenfeld’s chapter is valuable because he gives us an opportunity to understand the social dynamics and politicized history of the contentious debates and competing reform efforts within which efforts to improve mathematics education have taken place.

BRIDGING THE GAP BETWEEN SCIENTIFIC PRACTICE AND SCIENCE EDUCATION

In the second chapter in this first part of the book, Magnusson and Palincsar (chap. 2, this volume) describe their work on guided-inquiry science instruction. With its integration of philosophy of science, cognitive psychology, curriculum theory, and sociocultural theory, Magnusson and Palincsar demonstrate the value of adopting an interdisciplinary approach. By integrating knowledge of how scientists work with a conception of curriculum that is directly linked to inquiry, Magnusson and Palincsar argue for an approach to science education that builds on what we know about the process of scientific inquiry. By attaching this vision of science education to advances in cognitive psychology, Magnusson and Palincsar demonstrate how an understanding of text comprehension needs to be an integral part of our efforts to translate educational research and theory into practice in the domain of science education. The inclusion of a sociocultural perspective highlights the importance of understanding how cognition and curriculum are inextricably linked to community, participation, and culture. Here, Magnusson and Palincsar use Vygotsky’s (1978) notion of the zone of proximal development to create a coherent theoretical framework within which their efforts to translate theory and research into practice may be conceptualized and enacted. The instructional manifestation of this conceptualization is found in “notebook texts,” a pedagogical translation of the notebooks kept by practicing scientists. Magnusson and Palincsar provide a demonstration of how notebook texts are linked to research and theory. The chapter by Magnusson and Palincsar is distinctive because they show, in explicit terms, how each component of their intervention design was derived from a particular theoretical perspective. There is also a logical symmetry to the way they approach the task of translating research and theory into practice in science education. Magnusson and Palincsar begin with analysis of the practices of scientists and end with an intervention design that focuses on the practices of students as nascent scientists. Theory occupies the middle ground that connects these two varieties of practice. In this way, we believe the chapter by Magnusson and Palincsar exerts a positive stress on the title of this volume. Following their lead, we might have titled the book *Translating Practice Into Theory!*

CHANGE IN READING RESEARCH AND READING THE DYNAMICS OF CHANGE

In the chapter by Fletcher et al. (chap. 3, this volume), the authors describe how advances in research in reading have influenced areas of practice both in schools and in the broader public sphere. Referring to work carried out in Texas, Fletcher et al. demonstrate how a well established body of knowledge from reading research has affected educational practice, state legislation, and national legislation related to reading instruction. Different from many other areas of research that have relevance for education practice, the body of knowledge on which effective practices might be based for reading has grown consistently over the past few decades. The momentum associated with this growth has spawned a series of legislative actions that are designed to facilitate and even mandate efforts to translate research into practice. One would think that the existence of convergent findings supported by strong political will would greatly enhance the probability of implementation. Fletcher et al. demonstrate that a solid research base augmented by political support provides no guarantee of success.

Focused on the problem of how to translate their research into practice at varying levels of scale (e.g., school, collections of schools, school districts, regions), Fletcher et al. (chap. 3, this volume) show the importance of understanding the dynamics of change and describe the way in which epistemological issues, social investments, fiscal resources, and limitations in the research base influence our ability to translate research into practice. One of the most valuable and clearly ambitious aspects of Fletcher et al.'s analysis is that they urge investigators to reconceptualize the problem as the intersection of epistemological conflicts and methodological variations related to reading research and instruction. Fletcher et al. argue for the reconciliation of the well-worn methodological dichotomies (quantitative vs. quantitative) and for the integration of epistemological oppositions. As an illustration of their position, Fletcher et al. review the work on the Texas Reading Initiative. Their work provides a compelling demonstration of how the formation of collaborative partnerships and the provision of support for teacher participation have facilitated efforts to translate research into practice. By describing major problems encountered in their experiences with the Texas Reading Initiative, Fletcher et al. provide us with a series of recommendations based on many years of theoretical and practical work focused on translating educational theory and research into practice.

QUALITIES OF EDUCATIONAL RESEARCH AND THE DEMANDS OF PRACTICE

Focusing on literacy, both for basic reading and for scientific literacy, Calfee et al. (chap. 4, this volume) describe the ways in which their work on three professional-development projects has brought into focus critical issues related to the translation of research into practice. Calfee et al. provide an analysis that urges the research community to reconceptualize fundamental views about research practice, research standards, and research applications. The analysis of research practices presented in Calfee et al.'s chapter portrays research as another instance of complex learning rather than as a purely technical approach to knowledge production. The discussion of standards has implications for how the notion of "rigor" might be defined as investigators work to conceptualize the problem of translating theory and research into educational practice. Researchers in many fields of study use the term *rigor* to signify that the particular research study has adhered to the highest standards. Questions raised about the "demands of practice." introduced by Calfee et al. move the discussion of research rigor beyond the technical conventions of research methods. The idea calls for fundamental reconfiguring of the epistemological principles on which research practices are based. According to Calfee et al., work that meets the demands of practice displays methodological qualities and a high degree of conceptual coherence. As a theoretically oriented approach to the problem of translating research into practice, Calfee et al. also emphasize the importance of generalizability as a central concept for research that aims to have an impact on practice settings. One of the strengths of this chapter is that Calfee et al. provide a framework of issues within which recommendations for how to focus and improve our attempts to translate theory and research into practice may be developed. Key elements of this framework include redefinition of instruction as learning, a focus on sustained engagement with schools, a reconsideration of what counts as evidence at varying levels of scale (e.g., locally, nationally), and a call for adequate support for educational research. On a more practical level, Calfee et al.'s work helps think about ways to establish connections at various points (e.g., teachers, schools, school districts). In many respects, the chapter by Calfee et al. is of foundational importance because it raises fundamental questions about the set of assumptions upon which our practices as researchers are based.

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Notes on the Educational Steeplechase: Hurdles and Jumps in the Development of Research-Based Mathematics Instruction

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PART 1: A SUCCESS STORY (OF SORTS)

I start with a look on the bright side. A case can be made that a significant proportion of mathematics instruction in the United States has been changed for the better as a result of basic research in mathematical thinking, learning, and problem solving. In fact, mathematics may be the poster child for changes in practice influenced by basic research. I can tell this story autobiographically, for I experienced it firsthand—first as a student, then as a researcher, then as change agent. I begin with my school years. I was one of the happy (and therefore rare) products of what is now called the "traditional curriculum." The four major influences shaping curricular design at that time were

- The assumption that mathematics is a hierarchical domain with a ladder of skills that is well defined. It was assumed that such a hierarchy should define curricular structure. Addition and subtraction preceded multiplication and division, which preceded algebra, and so on up the ladder.

- The assumption, consistent with the organization of Bloom's (1956) *Taxonomy of Educational Objectives,* that mastery at any one particular level was critical for advancement to the next level.
- The assumption that "learning mathematics" and "mastering various mathematical facts, concepts, and procedures" are more or less synonymous.
- The assumption that tools had to be mastered before they could be used. Acquiring skills came first; then there was the possibility of using them in applications and problem solving.

The major theories shaping instruction at that time were behaviorism (I earned lots of gold stars for doing my work correctly) and associationism or connectionism (basically, the idea that repeated practice strengthens bonds between ideas—the theoretical underpinnings of "drill and practice"). Although I thrived on the traditional curriculum and went on to earn my PhD in mathematics, I was a rarity statistically speaking.

Mathematics was viewed by almost everyone as being both distasteful and difficult. On average, once mathematics became optional in the curriculum (about ninth grade), students dropped out of the mathematical pipeline at the rate of 50% per year. In 1989, millions upon millions of ninth graders were enrolled in mathematics courses. Hundreds of thousands were enrolled as college freshmen, and fewer than a thousand earned PhDs (many of these foreign nationals). The 50% annual attrition rate was an average across the population. Dropout rates from mathematics were much higher for African Americans, Latinos, Native Americans, and female students. In 1989,[1] for example, White male students constituted 40% of the U.S. population, Asians 2%; White male students and Asians constituted 78% of those earning PhDs. The curriculum was failing across the boards but even more so for some segments of the U.S. population (Madison & Hart, 1990; National Research Council [NRC], 1989). In a call for change, a 1989 report from the National Research Council, *Everybody Counts,* made the case as follows:

> Mathematics is the worst curricular villain in driving students to failure in school. When mathematics acts as a filter, it not only filters students out of careers, but frequently out of school itself.... Low expectations and limited opportunity to learn have helped drive dropout rates among Blacks and Hispanics much higher—unacceptably high for a society committed to

[1]As indicated in the body of this chapter, 1989 was a watershed year for curricular change. The National Council of Teachers of Mathematics' (1989) *Curriculum and Evaluation Standards for School Mathematics* catalyzed the development of a number of "reform" curricula, which differed in philosophy and pedagogy from the established "traditional" curricula.

> equality of opportunity. It is vitally important for society that all citizens benefit equally from high quality mathematics education. (p. 7)

Now I turn to the research that catalyzed change. The simple version of the story is that things began to change with the onset of the "cognitive revolution" (see, e.g., Gardner, 1985; Neisser, 1967, is considered the book that established cognitive psychology as a discipline.). Through the 1970s, conceptions of "subject matter understanding" were focused almost exclusively on content—on the specific mathematics (or history, or literature, etc.) that students were to learn. Over the course of the 1970s and 1980s, research in cognitive science in general and in mathematical thinking and learning in particular resulted in a radical rethinking of what it means to develop expertise in subject matter. By the mid-1980s, there was an emerging consensus (de Corte, Verschaffel, & Greer, 1996; Greeno, Pearson, & Schoenfeld, 1997; Schoenfeld, 1985) that the following can be fundamental determinants of individuals' performance in various intellectual domains:

- Core knowledge—knowledge of important facts, mastery of standard procedures, understanding of fundamental concepts, and familiarity with paradigmatic ways of operating in the domain (e.g., Greeno et al., 1997; Kilpatrick, 1985, 1992; Silver, 1987).
- The ability to implement problem solving strategies, also known as "heuristic strategies." These are not rules or algorithms that guarantee that a problem will be solved. Rather, they are rules of thumb, suggestions for making progress on difficult problems (Charles & Silver, 1989; Lester, 1994; Pólya, 1945; Schoenfeld, 1985; Silver, 1985).
- Effective metacognitive skills including monitoring and self-regulation (Brown, 1987; Flavell, 1976; Lester, 1985, 1994).
- Beliefs about, for example, oneself, the nature of the domain (a.k.a. epistemology), and appropriate ways of engaging with the subject matter (Greeno, Collins, & Resnick, 1996; Koehler & Grouws, 1992; Lampert, 1990; Schoenfeld, 1985; Shaughnessy, 1985; Silver, 1985).

By way of illustration, I briefly describe the role of each of these categories in mathematics and in writing.

Core Knowledge

There is, of course, a huge literature on knowledge acquisition and access. Simply put, knowledge is necessary for competent performance. General skills can carry you only so far; if you don't have the tools of the trade, you won't do very well at it. However, as the discussion of the next three categories indicates, they are only part of the story.

Heuristic Strategies

Various strategies in mathematics (e.g., draw a diagram, try to solve an easier related problem and then use either the result or the method to solve the original problem, establish subgoals, decompose the problem into subproblems) enable problem solvers to make progress on problems for which they do not initially have a way of solving. Strategies such as prewriting, "free writing," and using topic sentences enable writers to generate and organize text. Research over the third quarter of the 20th century established that such problem-solving strategies could be taught and that they enhanced problem-solving performance.

Metacognition

Effective monitoring and self-regulation during problem solving are major components of competent performance. Roughly speaking, these aspects of metacognition concern the effectiveness with which one employs the resources (specifically, knowledge and time) at one's disposal during problem solving. A major finding of the 1970s was that people often failed at tasks despite knowing the material. Suppose, for example, that someone makes a poor choice of direction in trying to solve a mathematics problem and pursues that direction doggedly. Whether the person has the knowledge to solve the problem is irrelevant: The useful knowledge lies inaccessible while the wrong problem-solving direction is being pursued. The same is the case with an author who loses track of the audience or with the main line of argument in what is being written. Large chunks of text may need to be discarded if the purpose of writing them was lost during the writing process.

Beliefs

Various kinds of beliefs shape the ways that individuals perform in a domain. Americans tend to believe, for example, that one's ability to do mathematics is innate and therefore not modifiable by effort. The Japanese tend to believe that mathematics learning is a function of effort—that anyone can do well at mathematics if the appropriate hard work is done. Needless to say, people will approach learning and problem solving differently if they believe that effort makes a difference. Clearly someone who believes that "writing is putting down on paper what's in your head" will go about producing text differently than someone who believes that writing is a process that involves planning and multiple revisions. Other beliefs about subject matter are learned from experience with the domain and shape how people go about working in the domain. Lampert (1990) summarized the case with regard to mathematics as follows:

> Commonly, mathematics is associated with certainty; knowing it, with being able to get the right answer, quickly (Ball, 1988; Schoenfeld, 1985b; Stodolsky, 1985). These cultural assumptions are shaped by school experience, in which *doing* mathematics means following the rules laid down by the teacher; *knowing* mathematics means remembering and applying the correct rule when the teacher asks a question; and mathematical *truth is determined* when the answer is ratified by the teacher. Beliefs about how to do mathematics and what it means to know it in school are acquired through years of watching, listening, and practicing. (p. 33; italics in original)

In short, an outcome of research in the 1970s and 1980s was that *content* (the classic view of subject matter), *process* (ways of engaging in the subject matter), and *belief systems/epistemology* (one's set of understandings regarding the nature of the enterprise) are all important outcomes of instruction—and thus important goals for it.

This research made its way into the practical arena largely by a series of historical accidents. Over the course of the 20th century, attention to mathematics education had waxed and waned. During periods of calm, issues of mathematics and science instruction pretty much faded from public view; but during periods of "crisis," they tended to become front-page items. In the mid-1950s, for example, the Soviet Union's success in sending the satellite sputnik into space catalyzed a great deal of activity in science and mathematics including various "hands on" science curricula and the "new math." Federal investments in science and mathematics instructional development flourished in the 1960s but then diminished through the 1970s for a number of reasons. One was apparent success. Our national space program got stronger after the post-sputnik years, and although the cold war continued, the atmosphere of crisis no longer obtained. A second was politics. One of the National Science Foundation (NSF)-supported curricula developed in response to sputnik was a hands on elementary school science and social science curriculum called Man: A Course of Study (MACOS). The first responses to MACOS were extraordinarily positive, and the curriculum was distributed widely. Lappan (1997) describes what happened afterwards:

> By the early 70s however, the mood of the country was changing. Distrust of federally funded materials was increasing.... "The first sign of impending trouble appeared in Lake City, a small market town in northern Florida (population 10,000), in the fall of 1970. Shortly after school opened in September, Reverend Don Glenn, a Baptist minister who had recently moved to Lake City visited his daughter's sixth-grade class." ... The school was under a court ordered integration plan. The teachers had chosen the materials because they felt they might help ease racial tensions.... Glenn claimed that the materials advocated sex education, evolution, a "hippie-yippee philosophy," pornography, gun control, and Communism. With support of a local radio station he broadcast four hour-long programs criticizing MACOS. This set off a growing series of attacks on MACOS over several years that led to a full

> scale Congressional debate of MACOS in both houses in 1975. NSF launched an internal review of its Education Directorate activities including an audit of the fiscal management of the project at EDC [the Educational Development Center, which produced MACOS]. While the audit revealed little to complain about, the damage in a sense was done. Dow quotes the former acting assistant director for science education, Harvey Averch, "It was the worst political crisis in NSF history." (Dow, 1991, p. 229) (Lappan, 1997)

The upshot of the MACOS controversy was that until the appearance of the National Council of Teachers of Mathematics (NCTM) *Curriculum and Evaluation Standards for School Mathematics* (1989), there was negligible support for curriculum development at NSF. This story is important in two ways. First, it establishes the context for the next period of crisis and response. Second, it documents the importance of politics, writ large, on the processes of education. Those are part of the current context as well.

To continue the narrative, in the 1980s, the nation was responding to yet another crisis, this one economic. The U.S. economy was faltering as the Japanese and other Southeast Asian economies flourished. The most prominent national report, commissioned by U.S. Secretary of Education T. H. Bell in 1981, was *A Nation at Risk* (National Commission on Excellence in Education, 1983). Here is how the report began:

> Our Nation is at risk. Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world. This report is concerned with only one of the many causes and dimensions of the problem, but it is the one that undergirds American prosperity, security, and civility. We report to the American people that while we can take justifiable pride in what our schools and colleges have historically accomplished and contributed to the United States and the well-being of its people, the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people. (National Commission on Excellence in Education, 1983, p. 1)

It was within this political and economic context that the NCTM, a professional organization of teachers, decided in the mid-1980s to produce and recommend a set of (national) desiderata for mathematics curriculum and evaluation. At the time, no such frameworks existed in the United States. (In some countries, e.g., France and Japan, there is a national curriculum: The subject matter content that students encounter is specified by the ministry of education. In the United States, there was [and is] no national curriculum and no national examinations in mathematics. Some of the 50 states had frameworks for mathematics, but most did not. The nation contained some 15,000 school districts, which had varied degrees of autonomy in selecting curricular goals and instructional materials. There were varied degrees of accountability to state frameworks and assessments. However, there was a practical constraint: The de facto curriculum was the curriculum presented in commercially available texts, which were homogeneous.) Given the post-MACOS history at NSF described previously, there was no chance that NCTM's effort could be federally funded. NTCM invited some other organizations to participate and then put together a team of two dozen writers whose charge was to construct a vision of mathematics education for the nation.

The result, *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989), known as the *Standards,* had profound impact on American education, catalyzing the "standards movement" in a wide range of disciplines. However, I take things one at a time. The *Standards* were written by NCTM for its members (mathematics teachers) and a somewhat broader constituency, those interested in mathematics education. They are not a research document: 258 pages of curriculum goals and examples are buttressed only by a page and a half of references, most of which are general. The language of cognitive science and the research-based warrants for the vision presented are not to be found in the *Standards*. However, they were very much in the mix as the *Standards* were crafted. The preceding two decades of mathematics education research shaped the *Standards* in profound ways. Gone was the simple-minded notion of mathematics as a hierarchically ordered discipline that students were to march through in straightforward ways, mastering the content at level n before moving on to level $n + 1$. In its stead was a much richer view of mathematics, one that was to prove controversial. That view, in the light of *A Nation at Risk* (National Commission on Excellence in Education, 1983) and national statistics on mathematics enrollments, was more democratically oriented—the goal was high-quality mathematics for all, not just the elite. Equally important, it reflected current research views that processes (such as reasoning, communication, and problem solving) and worldview (including disposition toward mathematics) were outcomes every bit as much to be desired as mastery of mathematical content. In a radical departure from past practices, the *Standards* identified the following as the first four standards for mathematics teaching and learning at every grade level:

- Mathematics as problem solving.
- Mathematics as communication.
- Mathematics as reasoning.
- Mathematical connections.

Within the context of these process goals came the delineation of specific content to be learned. Applications and problem solving were no longer seen as activities to be engaged in after the content was mastered; instead, they were seen as possible contexts for the learning of mathematics.

The *Standards* (NCTM, 1989) had far more impact than its authors had dared imagine. They exemplified the potential for consensus in important subject areas at a time of national crisis. Within short order, the standards movement was born: the NRC orchestrated the creation of the *National Science Education Standards* (ultimately published in 1995 by the National Research Council), and disciplines as diverse as history and English worked on standards of their own. This burgeoning sense of mathematical consensus, along with the recognition that the commercial sector was not likely to produce curricular materials consistent with the *Standards,* led the NSF to support mathematics curriculum development once again. The NSF issued requests for proposals (RFPs) for the development of curricula and assessments aligned with the *Standards*.

The RFPs went out in the early 1990s. NSF provided support for a small number of grants to develop innovative curricula aligned with the *Standards* (NCTM, 1989). Typically, funding was in the form of an n-year grant to produce n years of curriculum—for example, 5 years of curriculum in 5 years. (For a list of those curricula and links to their sites, go to the Mathematically Sane Web site, at <http://mathematicallysane.com/links/nsfprojects.asp>; for a detailed assessment of the curricula, see Senk & Thompson, 2003.) In effect, the curricula were finished in the late 1990s. Preliminary testing of those materials was done during the development and small-scale implementation of the final versions of the curricula. The results of large-scale testing of the curricula are just beginning to accumulate.

Figures on textbook adoptions are difficult to construct because of publishers' proprietary data, but those who are familiar with the textbook market estimate that *Standards* (NCTM, 1989) based curricula account for roughly 10% to 15% of current textbook adoptions. Overall, the evidence in favor of well-designed curricula aligned with the research-driven view embodied in the *Standards* is compelling. As I noted previously, most of the test results are preliminary. However, they are quite consistent.

Senk & Thompson (2003) provide the first comprehensive review of "reform" curricula in mathematics, with chapters describing evaluations of each of the major curricula and summary chapters providing across-the-board commentary. The results described have to be taken with a grain or two of salt, for many of the studies reported were conducted by the curriculum developers in "beta testing" environments rather than in regular field conditions. Nonetheless, many of the studies included comparisons with traditional curricula, and the pattern of findings is clear. Putnam (2003) summarized the results of the elementary curriculum evaluations as follows:

> Students in these new curricula generally perform as well as other students on traditional measures of mathematical achievement, including computa-

> tional skill, and generally do better on formal and informal assessments of conceptual understanding and ability to use mathematics to solve problems. These chapters demonstrate that "reform-based" mathematics curricula can work. (p. 161)

Analogously, Chappell (2003) discusses the evaluations of three middle school reform curricula:

> Collectively, the evaluation results provide converging evidence that *Standards*-based curricula may positively affect middle-school students' mathematical achievement, both in conceptual and procedural understanding.... They reveal that the curricula can indeed push students beyond the "basics" to more in-depth problem-oriented mathematical thinking without jeopardizing their thinking in either area. (pp. 290–291)

The story is the same at the high school level, according to Swafford (2003):

> Taken as a group, these studies offer overwhelming evidence that the reform curricula can have a positive impact on high school mathematics achievement. It is not that students in these curricul[a] learn traditional content better but that they develop other skills and understandings while not falling behind on traditional content. (p. 468)

The trends reported here are clear and strong, but one must issue a methodological caveat. Many of the tests used in the studies reported were developed by the curriculum developers. Some standardization of testing for the broad range of content and processes now deemed appropriate as outcomes of mathematics instruction and adherence to rigorous methodological protocols must take place before such findings can be considered definitive. (See the discussion later in this chapter of the 2004 NRC report "On Evaluating Curricular Effectiveness: Judging the Quality of K–12 Mathematics Evaluations" (Confrey & Stohl, 2004) and the What Works Clearinghouse.)

An intensive series of studies in the city of Pittsburgh, Pennsylvania, indicates that when *Standards*-based curricula are implemented in consistent ways (i.e., where curriculum, assessment, and professional development are all aligned), the "performance gap" between Whites and underrepresented minorities can be narrowed. (See Briars, 2001; Briars & Resnick, 2000; Schoenfeld, 2002.) A series of comparison studies in Massachusetts, using the statewide assessment as the measure of performance, shows that fourth and eighth graders using reform texts "outperformed matched comparison groups who were using a range of textbooks commonly used in Massachusetts.... These performance gains ... remained consistent for different groups of students, across mathematical topics and different types of questions on the state test (Riordan & Noyce, 2001, pp. 392–393). Also, in the largest study conducted to date, the ARC Center, an NSF-funded project,